The Potential of Watershed Development for Enhancing Agricultural Livelihood: Three Essays from the Semi-arid Regions of India

Ph.D. Thesis

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To my dearest daddy

Abstract

The Watershed Development Programme has gained growing support among development policy planners since the 1980s in India. This programme is designed to facilitate sustainable rural development by building irrigation capacity of the, otherwise, rainfed agricultural regions. Irrigation capacity is built via the adoption of various soil and water conservation measures, which then facilitate recharge of groundwater tables within an identified micro-watershed (typically consisting of one or two village communities). The recharged groundwater table becomes the natural resource base from which farming households draw water for irrigation by investing in wells or other such assets.

The management of micro-watersheds are based on the principles of community based natural resource management. However, the irrigation access (wells) to this common pool resource of groundwater is privately and individually owned which deters effective monitoring of resource use through collective action.

This thesis is built on Ostrom's sustainability of socio-ecological systems (SES) framework and uses a three-essay format. Each essay uses econometric techniques in an attempt to identify particular factors that enable self-organizing ability of communities dependent on groundwater-based irrigation system for generating better livelihoods. The fieldwork was conducted in three villages belonging to the semi-arid districts of Ahmednagar and Jalna in the state of Maharashtra. Quantitative and some qualitative data was collected from nearly 670 households through household surveys.

The thesis is organised as three core essays and three supporting chapters. Chapter 1 provides a background to WDP in India and sets the context for the research questions. Chapter 2 presents the literature survey and provides the rationale for choosing SES framework over sustainable livelihoods. It also discusses the broader research methodology. At the end, chapter 3 includes a consolidation of inferences drawn from each of the three essays, and identifies their potential applications and future research direction.

The three essays address the research questions raised in this thesis. The first essay analyses the role that knowledge of the resource system (micro-watershed) among resource users, plays in modifying individual farmer's irrigation demand (modelled as crop choice). Two watershed communities located on either side of the ridge line of the watershed are compared. The second essay analyses the role that social capital plays in encouraging self-organization in the community. Social capital is modelled as social betweenness scores calculated by applying Social Network Analysis. A comparison between two villages located in two districts belonging to two different rainfall zones is made. The third essay conceptualizes 'water stack' (collection of irrigation access points) that a farming household owns. The relation between the water stack of the households and the resource use norms in the community is analysed. A comparative analysis between all the three villages is made in this essay.

Knowledge of the resource system, social capital and continued support from the agricultural extension agency were found to encourage self-organization and enforcement of resource use norms, resulting in good health of the micro-watershed system.

Declaration

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the preface and specified in the text.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text.

It does not exceed the prescribed word limit for the relevant degree committee.

Signed:

Rekha Bhangaonkar

Date:

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Chapter 1

An Introduction to Watershed Development Programme in India

Nearly, two-third of the cultivable land in India practices rainfed agriculture and it supports an agriculture-based livelihood of approximately 40% of the total population (Singh, 2018). Poverty is high and concentrated in these agricultural regions (Parthasarathy Report, 2008) and the Watershed Development Programme (WDP) is a principal strategy for poverty reduction. The programme is of particular relevance for improving rural livelihoods in the semi-arid rainfed agricultural regions of the country, because implementation of WDP facilitates securing a source of irrigation, or at least a source of protective irrigation such that the complete dependence on erratic annual seasonal rainfall for agricultural productivity could be reduced (Symle et al., 2014). Notably, these regions have been overlooked by the Green Revolution wave of the 1960s and WDP is envisioned as the necessary prerequisite for a more inclusive second wave of green revolution (Parthasarathy Report, 2008; Reddy and Mishra, 2010).

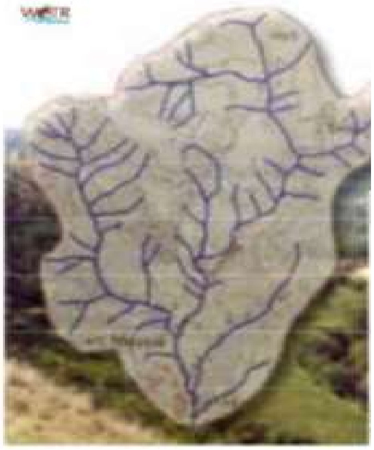
This chapter will briefly introduce the concept of a watershed and discusses the evolution of WDPs in India. Thus, Section 1.1 provides a technical description of what a micro-watershed is, Section 1.2 includes a historical account of WDPs, Section 1.3 highlights the more recent developments in the programme and finally, Section 1.4 introduces the research questions pursued in this thesis.

1.1 Watershed Development Programme

A watershed is defined as a natural hydrologic entity comprising of a land area in which the rainfall and its run off flows to a specific drain, typically a river or its tributary[1]. The biggest watershed is the river basin. A micro-watershed encompasses an area less than 1000 hectares, and typically falls within a boundary of a village or two. The boundary of a micro-watershed is referred to as its ridge line (Figure 1.1). This ridge line is de-lineated with reference to a common outlet (lowest tip in Figure 1.1). Water that falls within the micro-watershed will drain itself through the drainage lines (blue lines, Figure 1.1) to the common outlet.

[1] (Ref: Soil and Land Use Survey of India, Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India)

Figure 1.1 Illustration of a micro-watershed



Source: Watershed Organization Trust[2]

The WDP in India utilizes this unique hydrological property and designs measures of soil and water conservation to increase agricultural production of regions that are completely depend on rainfall for cultivation, particularly the semi-arid regions (Wani, et al. 2012). Through various soil and water conservation measures, WDP aims to restore degraded lands, increase their capacity to retain rainwater, harvest annual seasonal rainfall, recharge groundwater tables and reduce soil erosion; and as a consequent, increase the overall agricultural productivity within the watershed.

1.2 Implementation of WDP

The principal reference point for watershed planning is the river basin[3]; but due to constrains of/in implementing project in such vast geography, development policy practitioners have identified micro-watershed as the suitable unit for programme implementation (Common Guidelines, 2008).A micro-watershed is the smallest unit of watershed that is a representative of the complete natural, human and biotic[4] ecosystem nourished by a hydrological cycle of rainfall, runoff, recharge and evapotranspiration; it also a size conducive to community based natural resource management (Lobo, 2002).

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[2] Watershed Organization Trust (WOTR) is an institution championing the idea of participatory micro-watershed development and eco-system restoration to improve agricultural livelihoods. It was set-up in the year 1993 and its head office is located in Pune, Maharashtra.
3 River basin is the principal reference point for identifying watersheds, thus bigger units/scales of watershed planning is desirable to gain more conservation and water harvesting results (Batchelor et al, 2003; Kerr, 2007).
4 Biotic components are the living things that shape an ecosystem.

The Common Guidelines, 2008 for WDP recommends adoption of 'ridge to valley' approach for planning soil and water conservation treatments within a micro-watershed. To arrest soil erosion, afforestation and greening (increase grass cover) efforts are undertaken along the ridge lines. These efforts contribute to increasing the overall vegetation within a micro-watershed too. Along the slope of the valley, structures such as continuous contoured trenches (Figure 1.2) are constructed to slow down the speed of rainfall runoff. Slow movement of rainwater downwards through the valley allows percolation of water into the ground, improving the level of soil moisture within the treated region.

Figure 1.2: Various Land Treatments in a Micro-Watershed

Complementing continuous contoured trenches, drainage line treatments are carried out. De-silting of drainage lines and construction of check dams are some of measures implemented. Most check dams are built of locally available material of rock and mud but some that are located closer to the valley or common outlet of the micro-watershed are concreate structures (Figure 1.3).

Figure 1.3: Harvested Water – Check dams

Source: Watershed Organization Trust for Figure 1.2 and 1.3

Figure 1.4: Harvested Water – Percolation tank

Source: Watershed Organization Trust

Drainage lines carry the rainfall runoff through the valley to various points of water collection, namely called the percolation tanks (Figure 1.4). These tanks are constructed at locations that are scientifically identified based on hydrological principles. They are the feeder points for groundwater recharge within the micro-watershed. Recharged groundwater tables are vital resource in the WDP context as it forms the resource base from which farmers draw water for irrigation. Thus, the model of micro-watershed development as well summarized by

Crispino Lobo, a senior officer from Watershed Organization Trusts in a personal interview is, “through watershed development we attempt…Water that is running, we try to make it walk; walking water we try to stop; stopped water we force it underground”.

Figure 1.5: Transformation of a micro-watershed in ten years

Source: Watershed Organization Trust

The various soil and water conservation treatments undertaken in the WSD is accomplished only with active participation of its inhabitants. Participation by a good majority of the villagers, if not all are required for project implementation. Participation could be either in the form of wage-labour or monetary contribution. Theses contribution are referred to as *Shramdhan* (translation, voluntary labour). In villages were livelihood opportunities are very poor, Shramdhan is mostly in the form of wage-labour. Such contributions typically amount to approximately one-fifth of the total project cost. On completion of the project, a pot of funds equivalent to the labour days accumulated through Shramdhan is transferred to the Village Watershed Development Committee (VWDC). The VWDC is instituted for the purpose of upkeep and maintenance of the watershed in the initial phase of project implementation. Active participation by the community is believed to encourage the villagers to own up the development project.

To summarize, land degradation, loss of vegetation, soil erosion and complete dependence on rainfall for cultivation, keeps the agricultural productivity low in rainfed agricultural regions. Low productivity and thereby poor agricultural income further cause neglect of natural resources. WDP attempts to break this vicious cycle of poor incomes as a result of degraded natural resources and replace it with a virtuous cycle of sustainable agricultural livelihoods as a result of revived natural resources (Figure 1.5).

1.3 Evolution of WDPs in India

This section on the context of WDP, reviews literature which provides an account of the genesis of resource conservation efforts for improved agricultural productivity in the pre-independence era, conceptualization of WDPs in the post-independence planning era and finally accounts for recent developments in WDPs.

1.3.1 In British India (until 1947)

The origin of resource restoration/conservation actions by the government is traced to pre-independence colonial government's agricultural policies. Increasing population, growing variability in the level of agricultural production, and the inability to transport food surplus, in other words - poor food administration, and an almost complete dependence on rainfall resulted in increasing occurrence of scarcities and famines in pre-independence India (Davis, 2002). This led to the initial conservation plans and actions. The first institutional response to tackle food scarcity was setting up of The Famine Commission in 1880. The Commission recommended creation of provisions for protective irrigation in dry land regions and the revival of Department of Agriculture, Government of India. Simultaneously, a Department of Agriculture was set up in all the Provinces to assuage the severity of drought years (Kanitkar et al., 1960).

The Royal Commission on Agriculture in India was set-up in the year 1928, and it recognised the need for implementing afforestation measures to check soil erosion in the ravine tracts of United Provinces (corresponds to the current day states of Uttar Pradesh and Uttarakhand) and bunding (also known as The Bombay Scheme[5]) in the plains of Bombay

[5] In 1923, the first systematic and scientific study of dry land farming was conducted in the Bombay Presidency namely the Bunding and Dry Farming Survey and Development Scheme, later known as the Bombay Scheme. The scheme implemented construction of varied bund types which was the result of long years of research. The implementation of the Bombay Scheme began in the year 1933 after the Imperial Council of Agricultural Research agreed to finance the scheme. The Bombay scheme was implemented in Sholapur and Bijapur. The Council also recommended the emulation of similar methods in Madras Presidency, Hyderabad and Punjab (Kanitkar et al., 1960). Subsequently Hyderabad Dry Farming Practices, and Madras Dry Farming Practices were developed, however the research in this direction was terminated in 1943, as the time line set aside for these research commitments were 10 years (Singh, 1982).

Presidency (corresponding to the current day states of Gujarat, Maharashtra and parts of Karnataka) (Shah, 1998). The Commission also emphasised the need to develop research in favour of dry land crops (Kanitkar et. al., 1960). After the Bengal famine in 1943, The Famine Commission of 1945 emphasized adoption of soil conservation practice as an important relief measure and emphasised the need for scaling up of these techniques. However, soil conservation practices and efforts in the country were scattered, except in the Bombay Presidency (Shah, 1998).

The decade of the 1940s was a period of generalised food stress in British India. The separation of Burma in 1938 followed by the Japanese raid of Rangoon led to an abrupt end of a very crucial rice supply chain for India. An urgent need to meet domestic food supply led to the Grow More Food Campaign (1942). The campaign demanded increase in the area under food crop cultivation, use of double cropping methods where possible and diverting land from non-food cropping (particularly cotton) to food crops. It also demanded for increased irrigation supply through canal building and wells, increased use of manure and fertilizers and also the use of improved seeds (Knight,1947). The success of the Campaign is still a matter of debate[6] but there was a deep awakening to the need of achieving food security urgently. The partition of Pakistan from India further added to the woes of food security concerns as 32% of the irrigated land of undivided India went to Pakistan, drastically cutting down the potential for food production (Dantwala, 1991). Independent India's First Five-Year Plan began under these adverse circumstances.

1.3.2 In Independent India (post 1947)

The agricultural sector was the bedrock for achieving economic growth and attaining food security was a key concern of the First Five Year Plan (1951-56). The strategy adopted to increase food production was to increase area under irrigation, increase crop intensification, encourage use of better-quality seeds and also encourage consumption of manure and fertilizers - a strategy similar to the Grow More Food Campaign, 1942. The only exception was in the encouragement provided to cultivation of both cotton and jute along with food grain production (First Plan Report, 1951-56). The resource conservation measures focussed on conservation of forest and soil, and ensuring proper implementation of the protective measures were the

[6] (Knight, 1947) reports that the Campaign though did not add to the domestic food supply as was projected by the plan, but was able to increase the food production. Dantwala, 1991 opines that the success of the campaign was insignificant.

responsibility of the state governments. Agricultural production exceeded the production targets set out in the first plan and the Second Five Year Plan (1956-61) began amidst great enthusiasm.

The impressive growth achieved by the agricultural sector during the first five-year plan resulted in endorsing the agricultural sector as the one that could ensure stimulation to industrial growth. The strategy to increase production in Second Five-Plan was mainly by increasing area under irrigation, both minor and major irrigation. The importance of dry land farming was also recognised and contour bunding efforts were undertaken in the rainfed dry agricultural regions (Second Plan Report, 1956-61).

The Third Plan (1961-66) continued to pursue the production strategy of the former plan, while also bringing in the idea of high growth in agriculture through the use of improved variety of seeds. These seeds required more modern inputs, such as chemical fertilizers and the Plan emphasised the advantages of using them, particularly for food grain production. The influence of the Green Revolution Strategy for the modernisation of Indian agriculture is noticeable from this plan period. Contour bunding and terracing works made good progress in this plan period particularly in the state of Bombay. Centrally sponsored scheme of soil conservation in the catchment of 13 major river valley was also taken up during this plan (Third Plan Report, 1961-66).

An 'area saturation' approach through agricultural intensification and fertilizer use was the policy in the Fourth Plan (1969-74). The Green Revolution strategies were introduced in regions that were relatively more abundant in natural resources and irrigation facilities supporting agriculture was sufficient. Well-endowed regions were chosen on purpose to ensure better programme success. For the relatively less resource endowed regions, a Drought Prone Area Development Programme (DPAP, 1973-74) was initiated (Fourth Plan Report, 1969-74).

The Fifth Plan (1974-78) recognised certain oversights of the previous plans. It recognised the inefficiency in the use of irrigation potential that had been created[7] due to the late start in soil conservation measures in the river-valley catchments of major reserves. It is also in this plan period that water conservation measures were recognised. All India Soil and Land Use Survey and State Land Use Boards were set up to provide an overview of land use

[7] The Command Area Development Programme was launched during this plan period. This Central government sponsored programme focussed on improving utilization of the irrigation potential created so that the gap between irrigation potential and its utilization could be narrowed.

and conservation problems. The Desert Development Programme (DDP, 1977-78) was initiated to the end of this plan period (Fifth Plan Report, 1974-78). The Sixth Plan (1980-85) continued with the strategies of the Fifth plan. Small watershed (1,000-2,000 hectares) development programmes and Integrated Wasteland Development Programme (1989-90) were initiated during this plan.

It is the Seventh Plan (1985-90) which created a focus for the need to improve efforts to support rainfed agriculture and initiated the National Watershed Development Programme for Rainfed Agricultural Regions (NWDPRA). The initiative aimed to harvest water in low rainfall regions and increase agricultural productivity and minimize yields risks. The Eighth Plan (1992-97) extended watershed management programmes to cover more area. Every administrative block that had less than 30% of its land under assured irrigation qualified for micro watershed development initiatives and was covered under the programme. Soil and water conservation programmes were also extended to inter-state river valleys. A technical review committee of DPAP and DDP, known as the Hanumantha Rao Committee (1994) recommended an integration of these area development programmes and addressed the need to encourage community participation effectively. The role that non-government organisations can play in social mobilization and participation of the community was positively reviewed.

The Ninth Plan (1997-02) was guided by the Committee's review and an integrated approach to area development programmes at a watershed scale was adopted. Integrated watershed management in the catchment of flood prone river soil conservation in the catchment of River Valley Project continued. The Tenth Plan (2002-07), was distinctive in its emphasis on the need to rescue degrading lands and initiated use of technology in mapping resource conditions and prioritizing areas of focus accordingly. The introduction of soil-surveys at the level of the district was one of the key initiatives of this plan. Watershed development was upheld as a means to check degradation, bridge the gap in agricultural productivity and improve the basic source of water and irrigation needs. Watershed Development Funds with a corpus of ₹2 billion was allocated to the National Bank for Agriculture and Rural Development (NABARD) to encourage participatory watershed development initiatives. The Eleventh Plan (2007-12) focussed on development of water resources and the efficient management of water resources. Amelioration of the shortage in water supply for irrigation and non-irrigation purposes was the focus. As the Twelfth Plan (2012-17) was drafted, there was a shift in the economic thinking in the country, with the decision being made by the Indian government to move away from five-year planning to annual planning since 2015.

1.4 WDP in India since the 1970s

WDP is envisioned as a key intervention for improving rural livelihoods. It is also a point of convergence[8] for various other rural development programmes which focuses on sustainable rural livelihoods, specifically in semi-arid regions of country. Since the 1970s numerous resource conservation programmes have been implemented by the Ministry of Rural Development. As mentioned earlier, the WDP implementation approach have undergone drastic changes from being a top-down structural intervention under DPAP and DDP programmes to incorporating a more participatory approach through the Integrated Watershed Management Programme (IWMP). Table 1.1 provides a detailed timeline including inception of various key programmes of watershed development, guidelines and policy revisions.

Table 1.1 Evolution of Watershed Development Programmes and Guidelines in India

Year	**Program/Policy/Guideline**	**Major Objective**	**Relevant Institution**
1973-74	Drought Prone Area Development Programme (DPAP)	Economic development and mainstreaming of drought prone areas through soil and moisture conservation measures	Ministry of Rural Development
1977-78	Desert Development Programme (DDP)	Minimization of drought and desertification through reforestation measures	Ministry of Rural Development
1989-90	Integrated Wasteland Development Programme	Regenerate degraded non-forest through silvipasture and soil and water conservation on village and micro watershed scale	Ministry of Rural Development
1990-91	National Watershed Development Project for Rainfed Areas	Sustainable natural resource management, enhance agricultural production, restore the ecological balance, reduce regional disparities, and create sustainable employment opportunities in rainfed regions	Ministry of Agriculture
1992	Indo-German Watershed Development Programme	Rehabilitate micro watersheds for the purpose of regeneration of natural resources and sustainable livelihoods using participatory approach	National Bank for Agriculture and Rural Development (NABARD)[9] and Watershed Organisation Trust (WOTR)

[8] http://nrega.nic.in/Circular_Archive/archive/Draft_IWMP_MGNREGA_Guidelines.pdf accessed on 5:5:16

[9] NABARD is a financial institution established in the year 1982 through an act of parliament (Act 61). The institution began as a partnership between Government of India and Reserve Bank of India, but at present it is fully a government organization dedicated to provide financial support for rural development.

1994	Hanumantha Rao Committee	Technical Committee on DPAD and DDP	Ministry of Rural Development
1994	Guidelines for Watershed Development	Provide common guideline for WD focussed on the watershed scale having a participatory focus.	Ministry of Rural Development
2001	Common Guidelines for Watershed Development	Update the 1994 WD guidelines to have a more participatory and project specific focus with greater flexibility in implementation	Ministry of Rural Development
2003	Hariyali guidelines	Integrate community institutions more meaningfully in DDP, DPAP and IWDP in a more meaningful manner	Ministry of Rural Development
2006	Parthasarathy Committee report	A technical committee to evaluate DPAP, DDP and IWDP. The Committee's report serves as the basis of the Neerachal Guidelines and the NRAA	Ministry of Rural Development
2006	National Rainfed Area Authority	Create common guidelines for all Watershed Development schemes under different ministries for development of rainfed farming systems	Planning Commission
2006	Common Guidelines for watershed Development (Neeranchal) released	Promote a fresh framework to guide all Watershed Development projects in all the departments and ministries	National Rainfed Area Authority and Planning Commission.
2008	Common guideline for Watershed Development (Revised)	Integrated Watershed Development Programme (IWDP)	National Rainfed Area Authority
2009`	Integrated Watershed Management Programme	Consolidated DPAP, IWDP and DDP; adopted a cluster approach of watersheds (1,000ha to 50,000ha scale)	Ministry of Rural Development
2011	Revised Common Guidelines for Watershed Development released	Provided amendments to 2008 guidelines based on clarifications and suggestions from concerned ministries, departments, state governments and NGOs	National rainfed Authorities and Planning Commission
2013	Revisions added to 2008 Common Guidelines	Add new features to 2008 Common guidelines to ensure momentum to IWMP while strengthening its innovative features	Ministry of Rural Development

Source: Gray and Sindiri,2013. Revised by the author

In addition to the transformation in WDP implementation strategies, the objectives of the interventions too evolved over time. From a sole focus on increasing agricultural productivity, there was a move to embed stability and sustainability of rural livelihoods at the core of water development policy discussions. The incorporation of the word 'Integrated

Watershed Management Programme' in 2009 highlights this aspect. It also drew attention to the relevance of diversifying the sources of household rural income. Further, WDP which was exclusively within the ambit of government departments, opened doors to non-government organisations and foreign donors since the early 1990s. The involvement of non-government agencies, in particular, encouraged participatory approach for programme implementation.

1.5 Community Participation and WDP: Success Stories

Since 1980s, WDP have attracted considerable amount of funds. Turton et al, 1998, estimates annual turnover of nearly £ 300 million and a cumulative total investment of ₹ 24 billion in the 1990s (Farrington et al. 1999) and an estimated cumulative total of ₹ 286 billion (Wani et al, 2008) in the 2000s. There has been a number of revisions to the programme design to improve its development impact. This section summarizes some of the case studies that illustrated a significant development impact and thereby inspired policy thinkers to revisit and restructure the WDP framework.

Case1: Sukhomajari Village, Haryana

The Sukhomajari village is a model that showcased successful management of forest and water resources through community based participatory management of common resources. The village is located in the Ambala district of Haryana state. Development projects in the village began in the 1970s when Mr P R Mishra, an Officer from the Central Soil and Water Conservation Research and Training Institute in Chandigarh made an attempt to reduce siltation of Sukhna Lake near Chandigarh. To reduce siltation, check dams were constructed and re-vegetation (afforestation) in the catchment area of the lake was taken up. However, efforts to arrest siltation failed because of deforestation. The villages in the catchment were dependent on the forest for their livelihoods.

Mr. Mishra in a fresh attempt to rejuvenate the lake, constructed tanks in the village that facilitated harvesting of seasonal rainfall. The otherwise rainfed crops now had access to a source of assured irrigation which catalysed agriculture growth. The community's dependence on the forest for grazing declined, consequently vegetation in the catchment improved resulting in an effective check on silting.

Peculiar to this success story is the separation of land and water rights. The water harvesting tank provided equal share of water to both the landed and the landless in the community.

Case 2: Ralegan Siddhi Village, Maharashtra

The village is situated in the Ahmednagar district of Maharashtra. It was struggling with the issues of poverty, alcoholism, degraded agricultural land and lack of water for livelihood and drinking purposes. The transformation of the village began when Anna Hazare a native of this village returned to the village after his service in the Indian army.

Hazare had travelled wide and was inspired by the work of Swami Vivekananda, Gandhi and Vinoba Bhave. He had a vision and a plan for rescuing his village. To garner attention of the villagers, he mobilized some donation and expressed his interest in renovating an old temple in the village. He was able to gather a few villagers who lend him a helping hand. The renovation of the temple earned him a place in the village and the temple became a place for gathering and discussions.

He then, to mitigate water scarcity in the village, successfully motivated the community to build a percolation tank. Construction of the tank was undertaken in the year 1975 and unlike other summers until then, the villagers had water that year. The community was impressed with the initiatives of Hazare and elected him as the head of local government. During his leadership, he laid out and enforced five principles which he envisioned will result in the development of the village community. Bans were imposed on (1) open grazing (2) tree felling and (3) consumption of liquor, and people were encouraged to (4) adopt family planning and (5) devote voluntary labour or *Shramdan* for community development initiatives. These principles are endorsed by many community development programmes. The case of Ralegan Siddhi village, was described as an inspirational model in the Hanumantha Rao Committee Report.

Case 3: Social Centre, Maharashtra

The Social Centre is a voluntary agency based in Ahmednagar district of Maharashtra. The centre was established in the year 1969 by a Jesuit missionary. After nearly two decades of working with the village communities, the Centre approached a poor village of Pimpalgaon Wagha and expressed its interest in undertaking community support services in the village. Subsistence agriculture cultivated under rainfed conditions and livestock constituted livelihood of the villagers. They expressed their need to improve the conditions of livestock to improve their livelihood. The Centre assisted the villagers in improving the condition of livestock.

On gaining the confidence of the villagers, the NGO attempted to inspire the community to undertake measures to contain soils erosion as the cultivated land in the village was in a poor and degraded condition. Rainwater harvesting too was encouraged to improve agricultural-based livelihood in the community. The Centre organized a field visit for a group of villagers to Adgaon village, a village that had the reputation of being a model village nurtured under the leadership of Mr Anna Hazare. Inspired by this success story, Pimpalgaon Wagha too wanted to undertake similar development initiatives. A village level watershed development committee was formed and it was made responsible for construction and monitoring of micro-watershed. This village too achieved success and its development model is the one that is endorsed under the Indo-German Watershed Development Programme.

Case 4: Sujala Watershed Development, Karnataka

Sujala is a watershed development programme administered by the government of Karnataka. This development initiative was funded through a tripartite cost sharing arrangement, between the World Bank, the state government and the village community. The project until now has covered nearly 1,270 villages in 7 districts of the state. The development programme was implemented during a period from 2002-07.

Capacity building and monitoring was considered to be the way to sustain the benefits generated through WDP. Thus, Sujala catered to capacity building at two levels, one at the personal level by further equipping the villagers with skills related to the profession they were already engaged with, and secondly by facilitating capacity building of local institutions.

NGOs were delegated with the responsibility of encouraging community participation in the WDP. For the landless households in the community, savings and credit groups (self-help groups) were formed. This group was also trained for various income generating activities. For the landed farming households, Area Groups based on common topography and location of the farmland were formed. The Group membership did not distinguish farming households based on their land holding size. The self-help groups and the Area Groups, together formed the Sujala Watershed Sangh (SWS). A member from the Panchayati Raj (Local government) and a state government officer were also members of the SWS.

An emphasis on monitoring, evaluating and learning from the outcomes was one of the key characteristics of this development model. The impact of soil and water conservation efforts were monitored through, socio-economic survey, transect walk, application of Geo-graphical Information Systems and focus group discussions. Social auditing as a method to promote transparency and accountability is a special feature of this model. Development impacts of the programme is continuously monitored and communicated to all in the village through wall paintings and photography. To ensure efficiency in financial dealings, transactions were through cheques, beneficiary passbook were maintained and book-keeping practices at various levels of local institutions and the NGOs were meticulously maintained too.

Case 5: Adarsha Watershed Development, Telangana

Adarsha watershed is a WDP of the International Crop Research Institution for Semi-arid Tropical Regions, India (ICRISAT). This initiative began in the year 1999 as a collaborative effort between ICRISAT, state government departments and NGOs; an approach termed as the consortium approach to watershed development.

The development agencies began their work after conducting a baseline survey of the topography and socio-economic conditions in the village. This micro- watershed encompassed an area of less than 500 hectares and was home to 274 households. Agriculture was the primary occupation and most households were farmers with an average land holding size of 1.4 hectares. Encouraging soil and water conservation practices were the key focus of the programme, and around 250 low cost water harvesting structures were created in the village. Availability of both surface water and underground water improved significantly after the programme implementation resulting in a significant improvement in agricultural yield. Nearly an 85% rise in productivity was reported along with an increase in crop diversity. A village that was primarily of cotton cultivators had diversified into horticultural crops too. The villagers played an active role in planning and implementation of the intervention with ICRISAT, and the partnership continues to demonstrate a successful model of ‘partnership of science and community’.

The choice of these case studies is based on them being referred to as success stories in the literature and particularly in the Parthasarathy Committee Report, 2008; a landmark report reviewing various successful models or approaches to WDP. Some of the lessons that these case studies highlights are; firstly, engaging with the community and winning their trust is necessary for successful programme implementation. The involvement of NGOs or other community-based organizations facilitate quicker and better acceptance of the project by the community as these organizations have the required experience of working with communities. Working in partnership with such organization is more likely to result in success of government initiated or donor aided development interventions. Secondly, all the case studies highlight the importance of active participation of all the members in a community, particularly the landless and other less privileged as crucial to project success. Thirdly, the cases draw attention to the nature of partnership between the development agency and the community. Working in close partnership with the community and allowing the development intervention to take the nature and a form that the community is most likely to accept is important. In other words, the programme design requires the ability to modify itself to uphold the needs of the community. Lastly, communicating benefits accruing from the programme is potentially an effective way of encouraging greater ownership and accountability of the project by the community, contributing to sustained benefits accruing from the project.

1.6 Research Questions

The first-generation programmes, those implemented prior to the 1990s, focussed more on the objective of conservation, and primarily adopted a purely technical solution to the problem. These heavily techno-centric remedial measures for resource degradation were implemented using a top-down approach. But, poor outcomes from such development initiatives forced the development policy makers and practitioners to reconsider their implementation strategy. The success achieved by an NGO/ leadership driven, and community managed development efforts, undertaken at a micro-watershed scale, provided some evidence for an alternative strategy to WDP implementation. Such instances encouraged the government to abandon the top-down techno-centric approach, in favour of a participatory approach to WDP implementation (Parthasarathy Report, 2006).

Some of the merits identified with this alternative approach, the participatory watershed development was: the active engagement by community would facilitate better appreciation for the need of the development intervention by the community; it would also enable the community to influence the design of conservation plans, and therefore build a sense of ownership of assets created through the project (Kolavalli and Kerr, 2002). Since late 1990s, many micro-watershed development projects have adopted a participatory approach and impact evaluation studies conducted across hundreds of micro watershed sites reported an average estimated benefit to cost ratio of 2:1 in such projects (Joshi et al., 2011).

However, literature also reported that though the project benefits improved with the adoption of participatory approach, its effectiveness declined when the project implementing agencies withdrew from the site after project completion (Reddy et al, 2004). One of the reasons explaining this undesirable phenomenon is the inequality in distribution of benefits as a result of the WDP. Inequality discourages active community participation or collective action necessary for sustaining the positive impacts of the project. This is the case even when the overall benefits from the project and particularly for the small holding farmers in the community have been positive, (Joshi et al., 2004, 2005, 2011; Reddy et al, 2004; Shiefraw et al.,2008). The willingness of the community to work together which was demonstrated during the programme implementation phase begins to wane in most cases.

Sustaining the benefits from WDP in the post-project phase is critical for livelihood sustainability in these regions. The argument, that increasing the ownership of the community in the project through participatory approach or implementing the project in the community only when the demand for the project arises from within the community (sometimes measured by the condition that the community should shoulder a share of the total project cost) as a route to ensure sustained project benefits requires reconsideration.

Samuel et al. (2007) finds that sustainability of WDP are determined by the choices that a community makes regarding the use of water resources that were created. Therefore, the local institutions and social arrangements in the community are more likely to play a key role in creating those pathways that would support project's sustainability (Reddy and Soussan, 2004). Further, there is also a general trend showing preference for both decentralized governance structures and participatory community-based management of watershed. This research therefore engages in identifying pathways through which communities organize their local resource governance institutions for achieving efficient management of micro-watershed resources, resulting in sustainable livelihood benefits from WDP.

Considering the association of governance of micro-watersheds with management of common property resources (Kerr 2007), Ostrom's framework for analysing sustainability of Socio-Ecological Resource System (SES) was chosen. The choice of this framework is explained with details in section 2.2 of chapter 2. With this background, the specific research questions pursued in the thesis are as follows.

1. What is the role that *knowledge of the resource system* plays in encouraging self-organization among farming households in the micro-watershed community?
2. What is the role that the *importance of the resource* and *social capital* in a community plays in encouraging self-organizing and collective action in the community?
3. And, what is the relation between the *household's choice of livelihood* (and thereby individual demand for water resources) and the *resilience of the community* as a whole in heterogenous resource-use setting?

Each of these research questions attempts to analyse the impact or influence of some of the factors listed in the SES framework. Knowledge of the resource system among its users, and social capital in the community are listed under User (U) characteristics influencing self-organisation, and sustainability and resilience under the identified Outcomes (O). Section 2.2 titled Theoretical Framework in the following chapter explains the SES framework in detail, and section 2.3 titled Conceptual Framework in the same chapter presents the application of the framework in the context of watershed development.

Each of research question mentioned above is pursued in three individual essays. The conclusions drawn from each of the research questions is based on empirical analysis. The field-notes collected during this research, have been the source of information for contextualizing the quantitative results. Primary data for analysis was collected through household surveys from three micro-watershed communities.

Essay 1 is a comparative analysis between two neighbouring villages, falling on either sides of the ridge line of a micro-watershed. Both the villages were covered under the same WDP, but as two separate projects around the same time. Studies analysing impact of WDP, have often found that agro-climatic conditions have significant influence on project performance. To control for the influence of agro-climatic conditions on performance of WDP, analysis, this essay restricts itself to studying two communities with similar agro-climatic and soil conditions. The difference in development of two micro-watershed village communities that started under similar conditions, around the same time, has been particularly addressed in this essay.

Essay 2, on the other hand is a comparative analysis between two villages, both semi-arid, but belonging to two different rainfall zones. One of them belonging to a low rainfall zone, and the other to a higher rainfall zone. In both the villages, agriculture is the primary source of income and is not support by agriculture allied actives such as livestock. The impact of the evolved social capital on resource use is analysed in these similar, yet distinct, regions.

Essay 3, is a comparative analysis of all the three villages, i.e the analysis of performance of WDP in heterogenous settings. Village 1 belongs to low rainfall, predominantly dependent on agriculture alone; Village 2 also belongs to low rainfall region but their livelihood is supported by agriculture and allied activities such as livestock income; and Village 3 which belongs to a higher rainfall zone with thriving agriculture livelihood. The relationship between choice of livelihood of a household and resilience of the community in heterogeneous resource-use settings across these villages, is examined in this essay.

Chapter 2

Literature Review: Sustainable Management of Micro-Watersheds in Semi-Arid Regions of India

Watershed Development Programme (WDP) attempts to achieve a balance between the objectives of conservation, production and equity simultaneously. However, each of these have potential trade-off with the others (Kerr, 2001). A deficiency in achieving any of the above-mentioned objectives result in jeopardising the sustainability of benefits accruing from a project (Samuel et al., 2007). This chapter, therefore, reviews literature on sustainability of WDP and identifies the crucial role that community-based governance may play in sustaining the programme benefits for a micro-watershed. Review also reiterates that watershed is a common pool resource (Kerr, 2007). Consequently, Ostrom's theory of sustainability of Socio-Ecological Systems forms the basis on which the conceptual framework, and thereby the arguments are raised in the thesis. This chapter concludes by elaborating on the research methods used and the process of primary data gathered through fieldwork, which eventually feeds into the empirical analysis employed for substantiating the hypotheses.

2.1 Sustainability of Micro-watershed

The sustainability of watershed is broadly identified with (1) good maintenance of the physical assets created under the programme and (2) sustainability of livelihood outcomes achieved thereby (Samuel et. al., 2007).

2.1.1 Maintenance of Physical Assets in a Micro-watershed

Soil erosion and drought disrupts agriculture-based livelihoods in the semi-arid regions of the country. To address these concerns, soil conservation and harvesting of annual seasonal rainfall in undertaken via a WDP. To efficiently achieve these targets, the soil and water conservation strategies are planned using a ridge to valley approach (Common Guidelines, 2008). Soil erosion is checked by afforestation and greening (increasing the grass cover) efforts undertaken along the ridge lines of a delineated micro-watershed. For harvesting annual seasonal rainfall, various technically planned structures such as - check dams, contour trenches, inter-connected pits, percolation tanks, and gabion structures - are constructed. These structures cause the rainfall run-off to slow down on its path to the bottom of the valley. The slow descent through the valley allows better percolation of water resulting in enriching soil moisture levels. The run-off finally collects itself in strategically located percolation tanks. Stored water in these percolation tanks facilitates recharging of groundwater levels, enabling an irrigation system based on groundwater.

Well-planned (technically planned) conservation design and well-maintained physical assets created to support conservation, play a vital role in rejuvenation of degraded natural resources. Some of the key indicators of well-kept micro-watershed sites are, reduced soil erosion, low levels of silt in the percolation tanks, recharge of groundwater tables, and higher survival rates of trees planted in the land brought under afforestation (Wani et al, 2011).

Unfortunately, most of these structures are less cared for once the development programme implementation phase is over and the project implementation agency withdraws from the community (Reddy et al., 2004). Publicness of property regime and lack of institutional capacity to encourage effective maintenance are some of the main reasons for this neglect. Most of these conservation structures are built in the common lands within a delineated micro-watershed and their upkeep and maintenance are the responsibility of the Village Watershed Development Committee (VWDC). But these local institutions, more often, are unable to take adequate care (Samuel et. al., 2007; Bouma et al, 2007). In comparing private cost and benefits, between investing in conservation structures in the common land or investing in privately and individually owned well(s) for irrigation to support intensification of agriculture; farmers have a higher preference for investing in wells (Bouma et al, 2007). The public good nature of conservation structures encourages farmers to free-ride and eventually they are completely neglected by the community (Samuel et. al., 2007; Bouma et al, 2007).

The VWDC are key institutions facilitating mobilization of the community for implementation of the project, but their effectiveness is largely in the shadow of the project implementation agencies. VWDCs trained primarily to assist the project implementation agency during the initial phase of the project and are rarely supported with knowledge/information required for the upkeep of watershed once they withdraw from the site. Identifying responsibility and taking implementation decisions for maintenance are not well understood, neither are they exposed to …. Planned use of water resources.

Contribution in the form of voluntary labour *'Shramdhan'* is a requirement in the programme implementation design and encouraging active participation through labour contribution was expected to build the necessary skills for maintenance through learning by doing process (Grey and Srinidhi, 2013). Participation does improve the chances of the project sustainability, but it does not necessary and directly transfer into encouraging a sense of ownership of assets created by the community. Consequently, supply of adequate skills required for the maintenance and monitoring of resources are unavailable (Samuel et. al., 2007).

The physical structures also suffered neglect due to wrong targeting and over-subsidisation. The conservation activities implemented by the village community mostly employed local labour and resources. In communities with high unemployment, the opportunity of earning wages labour above the market prices is one of the factors influencing social desirability of the project (Kerr, 2002; Bouma et al., 2007). Consequently, despite entrusted with financial endowments required for upkeep, local institutions face serious challenges in management of resources and have been unable deliver leaving the funds to remain idle (Samuel et. al., 2007).

2.1.2 Sustainability of Livelihoods in a Micro-watershed

Impact assessment studies (data analysed from 311 sites in Joshi et al., 2005 and a sequel analysing data from 636 sites in Joshi et al., 2011), find WDP results in increase of land under irrigated cultivation, crop intensity, productivity; all of which would enhance agricultural income and employment. While increasing income and employment of an agricultural household is the primary objective under WDP, the resilience built to cope with climate stress as result of programme implementation affects the quality of this enhanced livelihood outcomes achieved (Reddy and Soussan, 2004). Resilience built is dependent on the strength of social capital and the institutional arrangement in the community (Samuel et al.,2007). This idea is well summarized in the following statement

> "Technically the key to success is ensuring the appropriateness of the physical works to the hydrological regime. Socially the key to success is ensuring community planning and functioning in a way that ensures long-term vision of local watershed development prevails over short-term sectional/factional opportunism" (page 342, Reddy and Soussan, 2004).

However, the challenge is in achieving strength from social capital because the benefits from WDP are unequally distributed in the community (Kerr, 2002; Joshi et al., 2004). Increase in soil moisture content in the cultivated land, availability of water in the privately-owned wells for irrigation, rate at which groundwater recharges and fills-up the well for irrigation supply, are all dependent on the location of the field within a watershed. In most cases, households with agricultural land on the slope of the watershed (upper reaches close to the ridge line) earn relatively less agricultural productivity gains in comparison to households in the valley (lower reaches closer to the water harvesting structures or percolation tanks) of the watershed (Kerr, 2002).

Additionally, the benefits from watershed is also proportional to the land holding size of a farming household. Farmers with larger land holding will be able to distinguish between the quality of land across his/her fields. This would allow them to subject poor-quality land to food crop cultivation that are less risky to grow under adverse conditions, and allocate more productive land to cultivation of commercial crops with higher returns. Choosing a portfolio of crops, and allocating them to the appropriate land quality allows farming households to improve the chances of earning higher agricultural income. With small holding farmers, this opportunity of choice of a crop based on land quality is unavailable, encouraging them to bring even poor land under commercial cultivation yielding little gains (Samuel, 2007).

Increase in land under cultivation is a targeted outcome of WDP; in addition to increased land, farming households also shift their preference to cultivating more water consumptive commercial crops (Scott and Bouma, 2006). This implies by gaining access to irrigation is through private investment for groundwater extraction modes would encourage farmers to treat groundwater as a source of irrigation instead of a source of supplemental or protective irrigation (Batchelor, 2004; Scott and Bouma, 2006).

In semi-arid drought prone areas, access to irrigation plays a very crucial role in mitigating a situation of crop failure to fair/good crop yields. WDP have certainly resulted in creating a source of irrigation within a watershed; but (unintentionally) the extent of extraction of groundwater has also increased. With proliferation in the number of wells and borewells, the levels of water extracted is greater than the recharge even in a very wet year (Batchelor et al., 2004; Shiferaw et al, 2008). Easy access to pumping devices has facilitated a virtual race for groundwater extraction leading to groundwater depletion in the watersheds (Samuel et. al., 2007).

Knowledge of the current status of irrigation demand, and the anticipated future demand of irrigation, are preconditions for successful management of watershed. Increased availability in water often shifts the focus to more unsustainable water management practices (Batchelor, 2004). For achieving sustainable livelihoods, regulating groundwater use is necessary, which is typically achieved by social capital and institutional arrangement in the community (Samuel et. al., 2007). Hivre Bazaar, a stellar example of sustainable micro-watershed management, has resource use norms such as ban on borewells, cultivation of thirsty crops such as sugarcane or banana, and rules of water allocation are effectively enforced (Sangameshwaran, 2006).

Lastly, in most cases, the landless, livestock owners and women in the communities do not benefit; if not negatively affected from WDPs (Kerr, 2002). WDP require strict enforcement of bans on grazing and tree felling for effective soil conservation. The landless in the community often depends on these common lands for pastures and fuel woods. They typically depend on small ruminants for livelihood, and by banning of grazing in the common lands, they are forced to keep them in enclosures and stall feed. These households also depend on common land for fuel wood, which too is restricted with the enforcement of bans. By abiding to the bans, the landless actually offer an environmental service for which they should be remunerated (Kerr, 2002).

Discussions thus far in the literature, have focussed on the nature of benefits accruing from WDP, their distribution among the landed and the landless farmers, and the crucial role that social and institutional arrangements play to ensure sustainability of livelihoods in the watershed community. Unless social and institutional arrangements within the community takes cognizance of these aspect, inequality in distribution of benefits will be further aggravated. Benefits of public investment on public land must be seen as a public good, to be shared with equity amongst all in the sector (Parthasarathy Report, 2006).

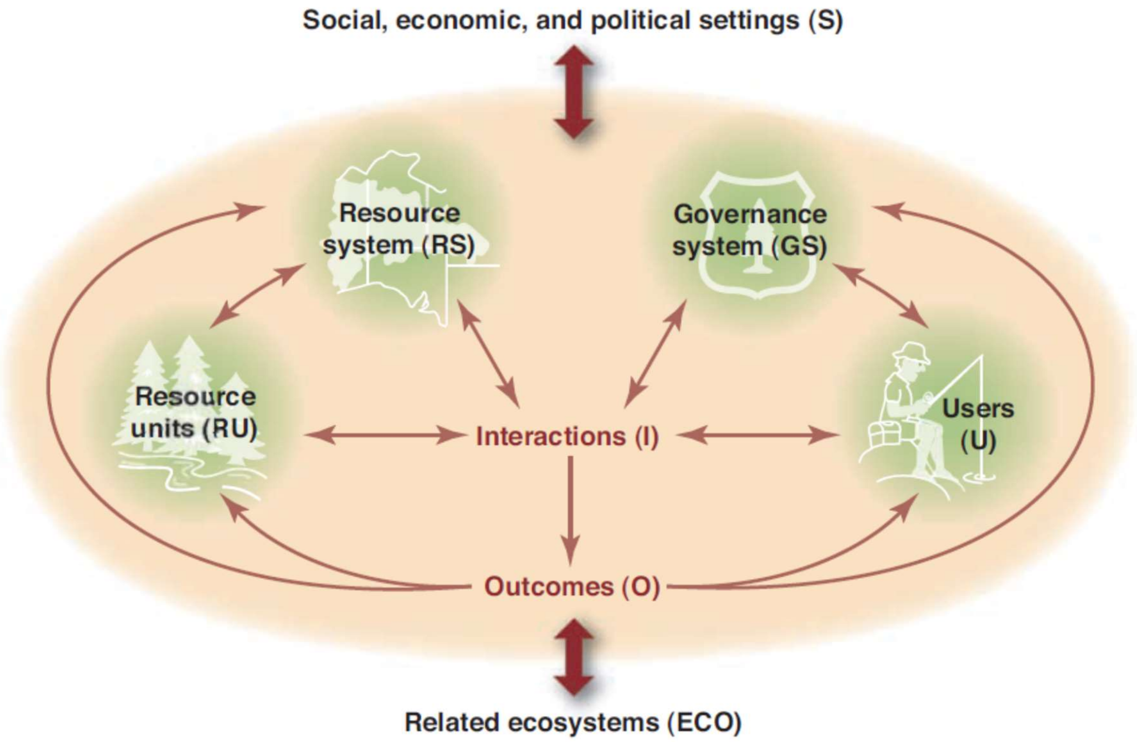
2.2 Theoretical Framework

Impact assessment studies are an efficient method to measure the immediate outcome from WDP. But, to gauge the relation between resource management and sustainable benefits from the programme, an alternative measure should be applied. Earlier studies (Baumann, 2000; Turton, 2000; Reddy and Soussan, 2004) have applied Sustainable Livelihood framework to analyse sustained benefits from WDP, however later studies applied the Social Ecological Systems (SES) framework for analysis as effective management of the resources - land under afforestation and groundwater - crucial to sustained benefits from the programme. Sustainable Livelihoods framework illustrates the relation between income and assets clearly; but serves limited purpose in the analysis of what motivates collective action in the community

(Baumann, 2000). The influence of governance/ political factors cannot be analysed with this framework. Consequently, the SES framework is chosen for analysis in this study[10].

The SES system in analysing interaction between human beings and common pool resource, recognizes four entities defined as the first level variables. These four are: Resource Units (RU), Resource System (RS), Governance System (GS) and Users (U), which Interact (I) with each other to produce Outcomes (O). The outcomes in turn feed back into the system making SES dynamic (Figure 2.1).

Figure 2.1: The First Level Variables in a SES (Ostrom, 2009)



Each of the first level variables are further elaborated and are referred to as Second Level Variables of the SES (Figure 2.2).

[10] In all these studies, the role of collective action, and the difficulties in achieving this feature are central concerns. The concept is therefore, not discussed as a separate subject of study.

Figure: 2.2 The Second Level Variables in a SES (Ostrom,2009)

<table>
<tr><td colspan="2">Social, economic, and political settings (S)
S1 Economic Development S2 Demographic trends S3 Political stability
S4 Government resource policies S5 Market incentives S6 Media organization</td></tr>
<tr><td>Resource system (RS)

RS1 Sector (e.g. water, forest, pastures, fish)
RS2 Clarity of system boundaries
RS3 Size of the resource system*
RS4 Human-constructed facilities
RS5 Productivity of the system*
RS6 Equilibrium properties
RS7 Predictability of system dynamics*
RS8 Storage characteristics
RS9 Location</td><td>Governance system (GS)

GS1 Government organization
GS2 Non-government organization
GS3 Network structure
GS4 Property-rights system
GS5 Operational rules
GS6 Collective-choice rules*
GS7 Constitutional rules
GS8 Monitoring and sanctioning processes</td></tr>
<tr><td>Resource units (RU)

RU1 Resource unit mobility*
RU2 Growth or replacement rate
RU3 Interaction among resource units
RU4 Economic value
RU5 Number of units
RS6 Distinctive markings
RS7 Spatial and temporal distribution</td><td>Users (U)

U1 Number of users*
U2 Socioeconomic attributes of the user
U3 History of use
U4 Location
U5 Leadership/entrepreneurship*
U6 Norms/social capital*
U7 Knowledge of SES/ mental models
U8 Importance of the resource
U9 Technology used</td></tr>
<tr><td colspan="2">Interaction (I) → Outcomes(O)</td></tr>
<tr><td>I1 Harvesting levels of diverse users
I2 Information sharing among users
I3 Deliberation process
I4 Conflicts among users
I5 Investment activities
I6 Lobbying activities
I7 Self-organizing activities
I8 Networking activities</td><td>O1 Social performance measures
(e.g. efficiency, equity, accountability, sustainability)
O2 Ecological performance measures
(e.g. overharvested, resilience, bio-diversity, sustainability)
O3 Externalities to other SESs</td></tr>
<tr><td colspan="2">Related ecosystems (ECO)
ECO1 Climate patterns ECO2 Pollution patterns ECO3 Flows into and out of focal SES</td></tr>
</table>

The design principles for commons (Figure 2.1 and 2.2) are adapted for the specific case of analysing sustainability of micro-watersheds and presented in the following section elaborating on the conceptual framework of this study.

2.3 Conceptual Framework

Well maintained land under afforestation and effective monitoring of groundwater resources determine sustainability of watersheds (Kerr, 2001). Of the two, management of groundwater is relatively more important, as efficiency in its management is likely to ensure adequate irrigation availability. Briefly, irrigation availability has the potential to transform agricultural livelihood (Reddy et al., 2004). But, effective management of these resources is difficult because of high exclusion cost and subtractive resource availability; the two main attributes of common pool resources (Kerr, 2007). Management of micro-watershed is further challenged due to unequal distribution of benefits from WDP. Collective action is needed for achieving resource use sustainability and thereby livelihood sustainability.

Adaptation of SES framework for the purpose of analysing factors that influence self-organization of resource users is presented below and shown in Figures 2.3 and 2.4:

Resource system (RS): A micro watershed encompasses an area between 500 hectares to 1000 hectares. In most cases, it constitutes a village community or two. The boundary of the micro-watershed is clear and distinct, but that of the groundwater is not defined. However, the access to groundwater is privately owned, for instance groundwater is extracted for irrigation through wells built with individual and private investment by its users.

Resource Unit (RU): Groundwater table is an underground surface in which the soil and rocks are saturated with water (Encyclopaedia Britannica[11]). It is a renewable resource and water table replenishes (or recharges) based on the average annual rainfall the micro-watershed receives. Wells are drilled into the water tables to access groundwater for irrigation and all the wells in a micro-watershed is interconnected to each other through the common ground water table.

Governance system (GS): The responsibility for the maintenance of assets created in the common lands i.e. land under afforestation arresting soil erosion and percolation tanks facilitating recharge of groundwater is with the local resource governance system – VWDC. As groundwater is individually accessed through privately owned wells, setting rules for resource use and enforcing them is also among its responsibility.

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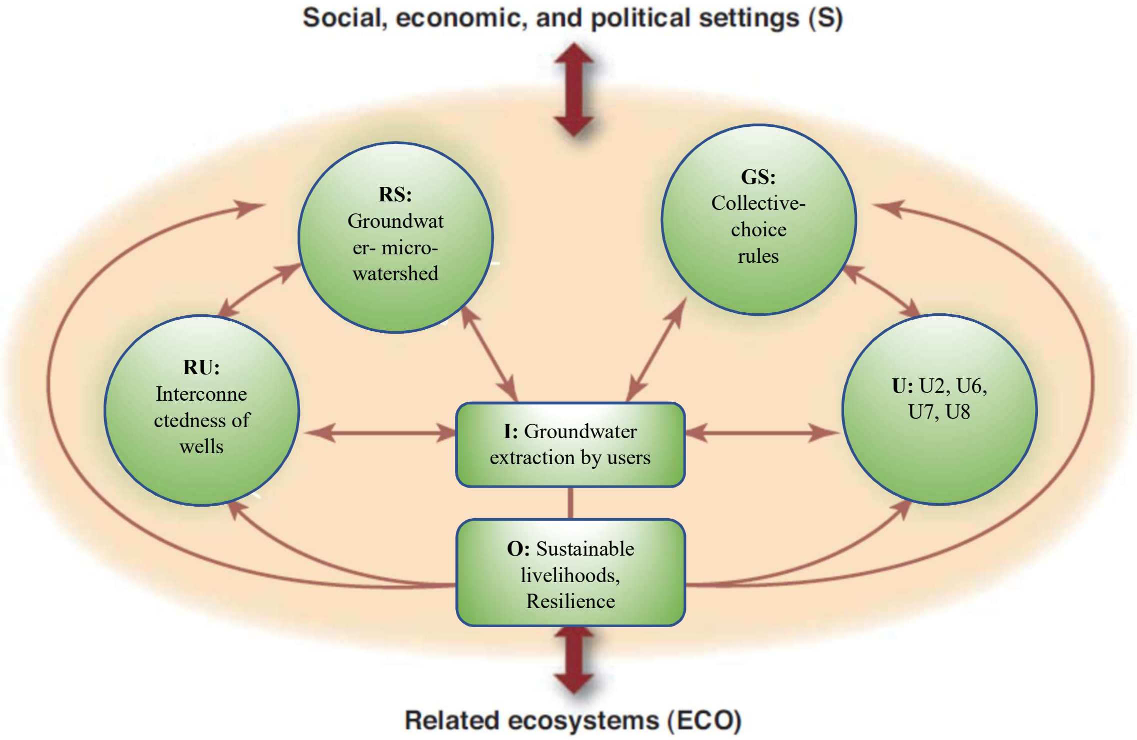
[11] https://www.britannica.com/science/water-table

Resource Users (RU): Agriculture is the primary means of livelihood for most households in a micro-watershed and the distribution of benefits from WDP is influenced by the land holding size. Households with larger farm size benefit more that households with smaller land holding as they are able bring larger share of land under commercial cultivation and also invest in multiple irrigation access sources.

Figure 2.3: The First Level Variables adapted for Micro-watershed Resource System



Source: Author's adaptation of The First Level Variables in a SES (Ostrom,2009)

Figure 2.4: The Second Level Variables adapted for Micro-watershed Resource System

Resource System (RS)	*Governance System (GS)*
(RS1) Sector: Micro-watershed	(GS6) Collective choice rules: Groundwater resource use rules
Resource Units (RU)	*Users (U)*
(RU1) Resource unit mobility: Groundwater	(U1) Number of users
(RU2) Growth or replacement rate:	(U2) Socioeconomic attributes of the users
Recharges depending on annual rainfall	(U6) Norms/Social Capital
(RU3) Interaction among resource units:	(U7) Knowledge of SES/mental models
Interconnectedness of Wells	(U8) Importance of resource

Interactions (I)	→ Outcomes (O)
(I1) Harvesting levels of diverse users: Groundwater extraction	(O1) Social performance level: Sustainable livelihood
	(O2) Ecological performance measure: Resilience

Source: Author's adaptation of The Second Level Variables in a SES (Ostrom, 2009)

Interaction and Outcome: Post WDP, groundwater table within the micro-watershed recharges, thereby improving water availability in wells. Most households in these villages depend on agriculture as their primary means of income, and they have a preference to privately own wells and extract groundwater for irrigation. To include more land under irrigated or high value commercial crop cultivation, farmers demand more groundwater from the watershed. To secure irrigation requirement, households may further invest in well deepening process, or may adopt techniques such as borewells. Though groundwater is renewable and recharges are based on the average annual rainfall, the proliferation of wells and deep punctures in the water table lead to deterioration of irrigation availability. Unchecked extraction of groundwater among households' results in depletion of groundwater. In poorly managed watersheds, instances such dry and unproductive wells are observed (Batchelor et al., 2003).

Management of watershed is the responsibility of VWDC, and an effective institution of local governance should enforce resource use rules (norms) in the community. Norms should influence groundwater extraction decisions of resource users in favour of sustainable use of groundwater, at the same time satisfying household's irrigation demands.

Resilience as an outcome is used in the context of households' ability to secure agricultural productivity even in the years of poor rainfall. In the semi-arid regions, farming households depend on annual rainfall for agricultural production. Changes in rainfall cycle, mainly an effect of climate change, have added to instability of livelihoods based on agriculture. Though irrigation potential of the watershed is dependent on the average rainfall, it is less vulnerable to vagaries in monsoon season and thereby builds resilience of their livelihoods.

2.4 Methodology

Studies designed to analyse long term impact of development project implementation typically work with data collected over time. In the context of this research, access to previously collected data was absent. To overcome the limitation in analysis due to lack of historically collected data, yet to satisfy the research objective of understanding the notion of sustainability of WDP, the research chose to study matured micro-watershed sites. A community were WDP was implemented at least a decade ago was the initial criterion applied for choice of fieldwork sites. Such matured sites would have inherently assimilated the programme impacts through the various stages of watershed development evolution over time, which would in turn get reflected in the current livelihood opportunities available in these communities.

2.4.1 Choice of the Region

The data for this study is collected from three micro-watershed villages communities from the state of Maharashtra. Nearly, 80% of the 17 million hectares of total cultivated land in the state is unirrigated, and a large share of it is classified as semi-arid. The state has a rich history of water management and the earliest WDP similar to the current structure of watershed development, namely, the Indo-German Watershed Development Programme (IGWDP) was first implemented in this state. This provides an opportunity to study villages that have a long experience in managing resources. The three villages studied belong to the first set of villages covered under the IGWDP; the WDP was implemented around late 1990s and was completed by early 2000s in all the three villages.

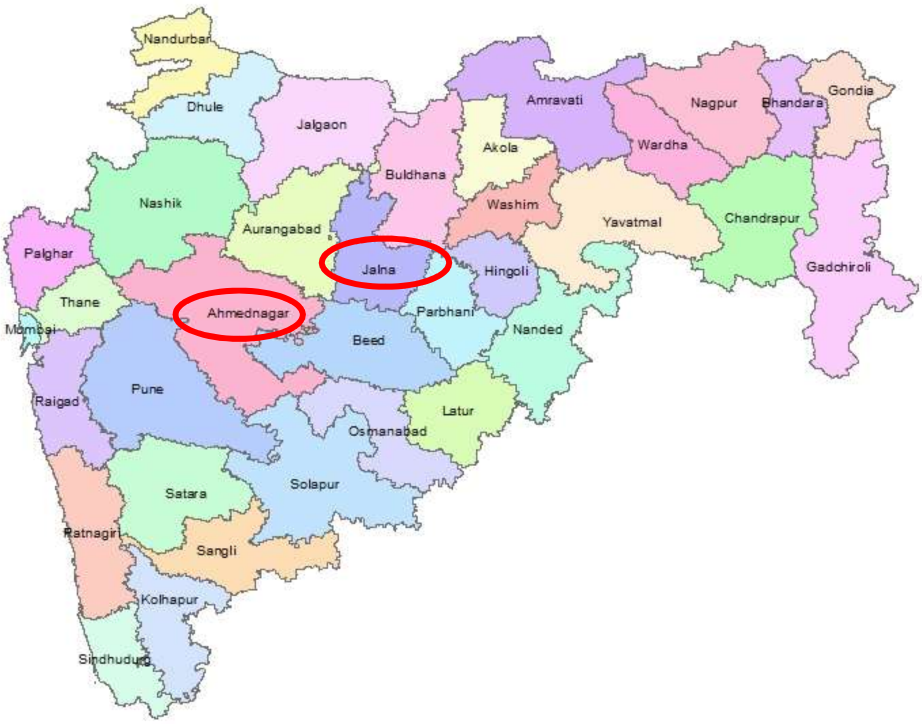
Prior to fully deciding on the research methodology and fieldwork sites, a scoping study was undertaken at the end of the First Year of PhD, in August 2016. During the scoping study, personal visits to key WDP implementing agencies in the state of Maharashtra were made, and an opportunity to interact with senior officers in these organization was pursued. Interaction with them helped identify potential watershed communities where fieldwork should be conducted. One of the agencies even helped arrange a visit to a potential study site. Thus, Village 2 was visited prior to fieldwork, and it contribute to preparations for fieldwork.

2.4.2 Choice of the Districts

The difference in the amount of annual rainfall a region receives has implications for the water harvesting capacity of a micro-watershed (Reddy, 2012). Livelihood benefits as a result of increased irrigation availability is more likely to occur in regions that receive higher rainfall. Based on the average annual rainfall a region receives, dryland agriculture[12] regions could be classified as –low rainfall regions (under 500 mm of average annual rainfall), medium rainfall region (greater than 500 but less than 1000 mm) and high rainfall region (greater than 1000 mm).

The districts of Ahmednagar and Jalna was chosen to represent two different dryland agricultural regions (Figure 2.5). The district of Ahmednagar belongs to the region that receives an average annual rainfall of less than 500 mm and district of Jalna, receives an average annual rainfall of approximately 720 mm. Secondly, the choice of districts was influenced by the location of watershed communities itself i.e. matured watershed community named as successful watershed communities in literature led to the selection of the districts.

Figure 2.5 Location of the districts chosen for study, State of Maharashtra



[12] Dryland agriculture refers to the form of cultivation that is completely dependent on the annual seasonal rainfall for growing crops.

In all, three micro-watershed communities that have been studied, two of which belong to Ahmednagar and the third one to Jalna. Sustainability of benefits from WDP is likely to be more challenging in a low rainfall region like Ahmednagar. Thus, instead of selecting one community, two communities located on either side of the ridgeline of the watershed have been studied. Yet another factor considered was the size of the communities in Ahmednagar. A micro-watershed community was only one-third the size of the community in Jalna.

2.4.3 Household Survey Design

The primary tool for collecting data was through household survey. The survey design, particularly the manner in which a survey question was articulated was influenced by the Indian Human Development Survey (IHDS) designed by the University of Maryland. A sample of the IHDS questionnaire was available online with an open access.

The primary purpose driving the design of IHDS questionnaire was to capture information on various occupations that a household engaged with to earn a living. To make the IHDS survey questionnaire more relevant to the context of watershed development, its design was adapted by excluding certain question that was less likely to inform the study context and by including more survey questions that would elicit information pertinent to the SES framework applicable to watershed development. The questionnaire was fully structured with close ended options provided for nearly all the questions articulated. The survey questionnaire was written in English first, and then translated into Marathi, the language of the communities studied. Language support for translation from English to Marathi was not required as the author is a native Marathi speaker.

The major headings under which data was collected includes household roster with information on number of members in the family, their age, gender and educational status, agricultural land holdings and irrigation status, agricultural decision making process including various association such as friend circle or agriculture extension services, agricultural aspirations, information on agriculture production, cost of cultivation and insurance, information on alternative sources of income and lastly a section with graphics that would illustrate preferences for ownership of irrigation assets and process of water resource management within the community. Survey questions were articulated with the intend to elicit information from the head of the household, typically the primary bread-winner. The survey questionnaire is included in Appendix 1.

After formulating the survey questions the household survey questionnaire, and a document describing the briefing that would be given to each household before administration of the survey, were submitted to the Research Ethics Committee of the Department of Politics and International Studies for review. The questionnaire and the briefing statement were approved by the Ethics Committee without revision.

2.4.4 Sample Design

Instead of working with data collected from a sample of households in the study villages, this research chose to collect data from all the members in the three micro-watershed communities. This decision was influenced by firstly, the small size of the village. Survey was first conducted in Village 2 which was home to 126 households. It was a small close-knit community where households were very aware of their neighbour's whereabouts. So, when a data enumerator approached a household, the neighbour too would enquire about the interview and its purpose. This inquiry would typically follow with an invitation to visit them as well. Personally, I found it very difficult to not accept an invitation as we stayed with the community during the entire fieldwork period and interacted with them through the stay. I feared that not including a household would send a signal of them being excluded.

Secondly, caste heterogeneity was a characteristic that transpired as the survey was being conducted. Again, being a small community with multiple castes in it made excluding a particular household difficult.

Thirdly, the primary method for analysis of data collected was through the application of econometric techniques. This implied that the number or size of the of observations too should be ensured for the application of multi-variate regression analysis. Loss of survey data due to errors and omissions during the process of data collection was anticipated.

Fourthly, there is a spatial dimension to the distribution of benefits from WDP (Pender and Kerr, 1998; Kerr, 2002; Joshi et al, 2004; Samuel et al., 2007). Households located in the base of the valley of the watershed were more likely to have more irrigation benefits than the households located along the slope of valley of the watershed. Further, farming households with larger land holding were more likely to benefit from the programme, than households with smaller land holding.

With all these concerns, a complete population survey rather that a sample survey was implemented in Village 2. To keep the method of data collection same across all the three communities studied, population survey was implemented in Village 1 and 3 too. Therefore, in all, nearly 678 household surveys were conducted. Loss of data due to errors and omissions in data collection was minimal (less than 5%). Selection of a team of experienced data enumerators, the presentation (spacing and answer columns) of the survey questionnaire and cross-checking survey sheets at the end of a day's work ensured efficiency in the process of data collection.

2.4.5 Positionality

Though I am a native of the state where the research was conducted, I have ordinarily been a resident of a city, and has had very limited opportunities to interact with rural population, and understand their lifestyle. Additionally, there is vast difference in the ways of living between the urban and rural spaces of Maharashtra. Thereby, distinguishing an urban dweller from a rural dweller could be effortlessly done. The language and the dialect spoken being one of the most prominent differences between the two. This difference could have hindered the possibility of free and spontaneous communication with the local community.

However, to overcome this hurdle in communication, I ensured that the team of data enumerators could speak the local dialect, and were familiar with the ways of rural living. Furthermore, selection of this team needed particular attention, because the household survey was the key instrument for data gathering, and it was planned to gather information from the entire population, and not just from a sample.

To organize a good team of data enumerators, help was sought from the same NGOs/ WDP implementing agencies with whom the researcher had interacted during the scoping phase of the research. In fact, during these initial discussions with the NGOs, the form of assistance that could be availed to facilitate execution fieldwork was discussed. The organizations were friendly enough and very kindly agreed to offer support.

Closer to the implementation of the fieldwork, expected requirements of members of the data collection team was communicated to the NGO. The particular requirements specified were: The candidate should (1) be a graduate, (2) have an experience of collecting socio-economic data in the field, and (3) have a rural background. The NGOs were able to provide a list of good candidates who met these criteria.

On receiving the list of potential candidates who could assist in data collection, I personally contacted each of the candidates though a telephone call. The telephone conversation included discussion about the candidates experience in data collection, academic background, and about the willingness to travel and stay as a team in the fieldwork sites. Consequently, there was, a team of 5 members (including me) for data collection in Villages 2. Similar process was followed to set-up teams for data collection from Villages 1 and 3. Village 1 being a site with more households, a team of 7 members was set-up. Since, most of the household heads were likely to be men, the data gathering team consisted of men in their 20s. I, along with another lady in her 30s, were the female members of the team.

Apart from the gender of the team members, care was taken to include one or two local persons, depending on the size of team. Inclusion of a team member who was very familiar with the community chosen for fieldwork was perceived to help the data collection process in two ways. Firstly, access to the community should become easier. Secondly, knowledge of the village community was expected to help in planning daily routine required for completing data collection within the stipulated fieldwork time.

It was also endeavoured to retain the same team across sites, as far as possible, in order to enhance the consistency of data collection, in addition to a fully structured questionnaire. Despite that, every individual data enumerator could have his/her own way of data entry and capturing other general observations from the worksite. The researcher ensured that these variations were also minimised by providing fairly exhaustive team training at the beginning of each cycle of data collection. The possibility of being able to work with the same team across sites would have helped save the initial learning time for the team members too.

With three different study sites, the fieldwork was planned in three phases. In each phase, data would be collected from one community. This process was planned in a staggered manner to make the task of execution of fieldwork more manageable. Particularly, managing a team for data collection implied, apart from taking care of the team during the entire duration of fieldwork, arranging for adequate finances towards their remuneration, lodging and boarding services.

The team and the researcher stayed together in the community for the entire duration of the fieldwork. The stay was facilitated by the WDP implementing agency. On arriving at the fieldwork site, the entire team visited the village headman and a few other gate keepers of the community. At these meetings, the purpose of the fieldwork and information on the identity of the researcher and her team members were communicated. These meetings and the discussions helped the village to acknowledge the team and cooperate with the data collection process.

As a consequence of a spread-out fieldwork plan, the agricultural cycles during which data would be collected, varied across sites. To ensure comparability across agricultural data collected for a particular agricultural cycle in a year, the tables for such data entry were formatted in a manner to minimize errors due to wrong entry.

Finally, bias could occur in the process of translating the survey questionnaire from English to the local language. However, as most of the survey questions had clearly set-out options to match with the households' responses, minimal loss of information in expected translating the responses back to English.

2.4.6 Implementation of the Survey

The average rural literacy in Maharashtra is approximately 77% (Census 2011). Therefore, most households studied were capable of filling in the questionnaire themselves. However, for making the process of data collection comfortable for the respondent, the survey was planned to be conducted in a '*conversational manner'*. In general, the survey questions are not sensitive in nature, however there are a few questions which collects data on the income levels of the household.

Prior to rolling out the survey, a day long orientation was conducted for the team of data enumerators. The orientation covered (1) an explanation of the research interest (2) the protocols that should be followed during the process of data collection and (3) an elaboration on conversational manner of conducting household survey. At the end of the orientation, the team set out to conduct a field trial of the survey.

The protocols followed in the data collection process was, every survey exercise began with the data enumerator providing a clear introduction of himself/herself, which followed with a brief narrative on the purpose of the survey. Participants were assured that the data collected from them will be well protected and not be shared with any agencies, but will be used solely for the purpose of academic research. The brief also informed the participants that the information they would share in the survey will be studied carefully to draw various research conclusions. A verbal consent pertaining to the willingness to participate in the survey was requested, and a consent by the respondent to do so was marked as 'yes' and signed by the data enumerator. Data from the respondent was enumerated in a conversational manner. Adopting such a method, though may consume more time than otherwise, helped the survey respondent to be at ease (relatively) with the process. It was explained to the household that, they were welcome to ask for any clarification or doubt that may arise in the process of data collection. Further, they could refuse to answer any question, a section of the questionnaire or the questionnaire in itself, if the household finds himself/herself in an uncomfortable during the process. They were assured that, despite the initial consent given, they may choose to discontinue the process anytime without providing an explanation. Fortunately, none of the surveys conducted had to be discontinued, neither did any household disagree to participate nor expressed concern over the use the data that they very kindly shared for academic research.

Protecting the data collected was very important to the research. Anonymization of data collected was guaranteed to the survey respondents. To ensure anonymisation of data, each household in the village was identified with a unique household number and not by the name of the head of the household.

The expected time taken for completing a household survey was about an hour and a complete population enumeration was plan in the research design. Thus, on an average 6 surveys per team member per day was the target set. Accordingly, the team would set out for collecting data early in the morning and return by early afternoon, completing nearly half of the work. The, other half of the daily target was attempted later in the evenings. This strategy of data collection worked well in the case of Village 2 and 3 because it was possible to arrange for accommodation of the team within the village itself, saving on travel time and transportation arrangement required. In the case of Village 1, surveys that were conducted in the morning hours met the household at their residence, but as the day progressed, farmers moved to their fields for work and data enumerators met with the farmers in their field. Data could not be collected in two work shifts because the distance between the place of accommodation and the villages was nearly 35 kilometres. This might have caused some inconvenience to farmers, but making alternative arrangements was not easy, particularly loading and boarding facilities available for the whole team was limited to about 15 days only.

At the end of the fieldwork in a particular site, every team member completed an equal number of surveys. This condition of equally distributing the numbers of surveys among the team was agreed upon at the beginning of the data collection plan. Laying down such a condition at the outset discouraged a sense of competition among data enumerators to conducted more surveys, on the contrary, it encouraged team work.

The survey was carried out over 14 days in Village 2 (23th December 2016 to 5 January 2017), 16 days in Village 1 (April 15th to 1st May, 2017) and 16 days in Village 3 (10th August to 25th August, 2017). It was possible to collect data from most of the households at the first visit, although some required repeated visits. Eventually all the selected households in the three villages were surveyed. In total 678 households were surveyed consisting of 376 households in village 1, 126 households in village 2 and 176 households in village 3. On completion of each day's data collection, the entire team met to recheck the filled-out questionnaires and discuss any difficulty encountered in the process of data collection. Most of the errors and omission were eliminated through this process of correction.

The survey schedules were in a booklet format and data entered in them with a pen. The forms were carried to Cambridge for data processing by the provision for an extra luggage to be carried along in the fight.

2.4.7 Reflexivity

Utmost care was taken to design the survey questionnaire and plan the protocols necessary for efficient enumeration of data. However, there were a few cases when the relatives of the household would gather, and would express their opinions, which then leads to the respondent to modify his/her answers. For instances, siblings choose to live near to each other and were quite aware of each other's whereabouts. They also had an opinion on each other's affairs and would express them during the survey. It was difficult to overcome such interference and those calibrated (re-considered) responses does create challenges to the quality of data collected.

Since the fieldwork sites were rural communities, the gender association of the researcher as a female was thought to hinder communication with male members of the community. While this was true in very few cases, most members of the community were able to communicate without much noticeable bias. However, it is possible that the presence of male team members may have downplayed this bias. Further, only in very few interactions, the caste identity of the researcher was enquired about. This too was a concern among the village elders in only one village among the three. But, after revealing the caste identity there were no further queries, potentially because the researcher belonged to a caste that was acceptable to them. The caste identity of the researcher too seems to have very little influence on the research positionality.

The support provided by the WDP implementing agencies for planning and execution of fieldwork in each of the study sites was crucial for the fieldwork to be executed without great difficulties. To acknowledge their support and as manner of expressing gratitude, this association was explicitly mentioned in the survey briefing, as well as was printed on the cover page of the survey booklet. Explicitly stating this association was anticipated to influence positionality of the research. The anticipation was that, such an association will establish legitimacy / credibility of the research in the community, facilitating the community to participate without fear. The basis of this positive bias was because, it was the WDP implementing agencies themselves who referred to these communities as examples of successful watersheds.

But, in the due course of the fieldwork, the researcher realized that Village 2 in particular had very mixed interpretations of this association. However, by assuring the villagers that the association served the purpose of acknowledging the support offered by the agency and that it did not have any other implicit meaning, better participation was encouraged. In other words, by convincing the villagers that the research was an independent endeavour by the researcher, purely for the purpose of achieving an academic degree, they were more willing to participate. Quite contrary to Village 2, villagers in Village 1 and 3, regarded the project implementing agency very highly and were very willing to participate in the whole process with more enthusiasm. In all cases, the association of the research for academic purposes was perceived as harmless. Notably, these communities also recollected their experience of interacting with other academic researchers who in the past have conducted fieldwork in their village.

Lastly, though not directly relevant to the positionality of the researcher in the study villages, the choice of the study villages is influenced by the WDP implementing agencies. During the organizing and planning phase of the fieldwork, a few WDP implementing agencies were contacted. While some agreed, some others refused to offer any form of support. One such agency refused as they believed that their watershed community was over-studied by academic and other research agencies. An invitation to visit this community was suggested but conducting household survey was refused as it would inconvenience the community. Another agency refused, because an agreement on the sharing of data between the researcher and the agency could not be achieved. A third agency also refused, as they were planning to conduct a household survey for the purpose of their own research.

Finally, the villages to which this research gained access were the ones chosen for the first generation of WDP intervention in Maharashtra, namely the Indo-German Watershed Development Programme. WDP were implemented between late 1990s and early 2000s in all the village communities studied in this work. The agencies were typically keener to showcase the villages communities where an improved micro-watershed development intervention was successfully, and more recently, implemented. However, emphasis on the age of the watershed community as critical to the study resulted in them implementing agencies providing access and support required for the study of the chosen villages. Thus, the choice of the villages transpired to, two micro-watershed villages communities located on the either sides of the ridge lines of a micro-watershed and another village community in a neighbouring district located in a different agro-climatic zone.

The irrigation potential of a micro-watershed is dependent on the amount of rainfall it receives. The two neighbouring villages on either side of the ridge lines despite having very similar agro-climatic conditions, developed to produce very different livelihood outcomes. The first essay in this thesis seeks to explain the factors that caused the difference in livelihood outcome among village with similar agro-climatic condition. Further, the second essay compares livelihood outcomes between villages where agriculture was the primary source of income, but they were located within two different agro-climatic zone, one which receives more rainfall than the other. Finally, the third essay examines various livelihood risk mitigation strategies adopted by all the three villages.

2.4.8 Following a Research Ethics Protocol

As mentioned in the previous section, identification of the communities for the purpose of study was guided and facilitated by the local WDP implementation agency. On agreeing with them the prospective villages that were to be covered as part of the study, the nature of the research, the use of data that will be collected, the method of analysis and the main tool of data collection - the design and content of the household survey questionnaire, were discussed with these agencies at length. These discussions were critical to understand the appropriateness of the research topic and its methods of data collection such that the members of the community were not distressed at all by participating. The researcher also requested the local project implementing agencies to facilitate the initial interactions with the community, so that the villagers would not be apprehensive of the identity of the researcher and the motive of the research. One of the main worries that communities have in giving away information is that, the data will be shared with some government agencies which will then result in some households to lose out on certain government benefits that they currently receive.

There was no sharing of raw data with either of the local project implementation agencies, however, on completion of the data collection and the initial stages of statistical data analysis, a presentation of the initial findings of the research was presented to one of the local development projects implementing agency. A more detailed study report based on the field data will be shared with the other agency shortly.

The researcher and the data enumerators worked as a team in the community. The team, as far as possible, moved about in the community together but dispersed at certain points to meet every household in the community. Quite often, the paths to navigate through the community and ideal locations for the team to disperse and reconvene was suggested by the members of the community. Safeguarding health of each member of the research team was the responsibility of the researcher. First aid kit and necessary medicines were kept in sufficient stock; these medical provisions were useful particularly during the fieldwork that was conducted in the summer. With temperatures soaring as high as 45°C, health difficulties due to dehydration was a challenge. Rehydration drinks were very useful in such tough times.

The research team emphasised that they were a group of students keen to engage with the community to learn from their experience. The community was fully able to appreciate that a detailed study report will be written at the end of the research which then has the potential to catch the attention of policy makers and development workers. The community was also receptive of the fact that their experience will be a source of learning for some other community, and they were in appreciation of this possibility.

On the whole, the fieldwork has been a very satisfying experience. All the communities which were studied were very welcoming and happy to share a conversation of their experience with watershed development. However, it must be admitted that it was much easier to engage with mostly happy and hopeful life stories, than the ones that were tinted with discontent. Further, what started as a team of individuals working together to collect data for the purpose of a single study village, developed to become a healthy collaboration across multiple study sites and with a potential of further long term association.

Essay 1

Harvested Water and Crop Choices: Sustainable Management of Micro-Watersheds in Semi-arid India

Abstract:

The Watershed Development Programme (WDP) in India facilitates sustainable agricultural livelihoods by rejuvenating the natural resource base within an identified area. WDP implementation provides irrigation to farming households that can be accessed through wells. Increased availability of irrigation encourages higher agricultural ambitions and consequently, active groundwater extraction. In the absence of effective monitoring of resource extraction, its depletion is inevitable. Effective local governance is crucial to resource sustainability, but the elusive nature of groundwater poses challenges. This research evaluates two features identified in Ostrom's sustainability of Socio Ecological System (SES) framework – the role of collective knowledge of the resource system (U7) and the importance of the resource to its users (U8) play in encouraging effective management. Data was collected from two mature watersheds located in the semi-arid regions of Maharashtra, India. The research finds that farmers with higher irrigation demand engaged actively with agricultural extension services. Also, collective engagement is seen to encourage development of site-specific resource management strategies, thus safeguarding resource sustainability.

Key words: Micro-watershed, groundwater-based irrigation system, knowledge of Socio Ecological System, collective action, agriculture extension agency, semi-arid India

E1. Introduction

Since the 1990s, the WDP has been gaining growing support among development policy planners and practitioners in India (Joshi et al, 2004a; Parthasarathy Committee Report, 2006; Joshi et al., 2008). WDP is designed to facilitate an increase in agricultural productivity through improved soil management practices, afforestation and harvesting of annual seasonal rainfall within an identified micro-watershed (Kerr, 2007). WDP results in recharging groundwater tables, enabling increased availability of irrigation that can be accessed through wells (Symle, 2014). WDP is particularly relevant to the semi-arid regions of India, where agriculture is primarily rain-fed and farmers have to contend with soil erosion and degradation of natural resources (Reddy et.al., 2004, Parthasarathy Committee Report, 2006).

Increased availability of irrigation post WDP encourages higher agricultural ambitions in communities. Crop intensification, crop diversification and increased land under horticulture are some of the popular indicators that measure the impact of WDP (Joshi et. al., 2008). A further consequence of a successful WDP is active extraction of groundwater. Unchecked extraction that exceeds rainfall harvesting capacity of the watershed, ultimately challenges both resource use and livelihood sustainability; a phenomenon more likely to occur in the watersheds receiving less rainfall within the semi-arid regions (Batchelor, et. al, 2003; Bharucha, et. al, 2014; Singh, 2018).

Sustainability of micro-watersheds is dependent on the effectiveness of enforcement of pre-agreed communal laws of resource use by the local institutions (Kerr et.al., 2002, 2008; Joshi et.al, 2004b). Despite decentralized local governance structures, communities face challenges in their effective management and monitoring. Subtractive availability of groundwater for irrigation and non-excludability of users, challenges effective management of this common pool resource (Wade, 1987; Kerr,2007, Shiferaw, et. al., 2008). Additionally, the elusive nature of groundwater resource intensifies the challenge. Alternative monitoring mechanisms are water (shadow) pricing (Shiferaw et. al. 2008) and groundwater use legislations (Joshi and Aslekar, 2018)[13].

This research contributes to the literature on sustainable management of common pool resources by examining factors that encourage self-organization and collective action in a SES with a focus on demonstrating the role that collective knowledge of the resource system among its users may play in sustaining collective action when the resource is of higher importance to

13 For forest management, local governance institutions through increased participation and rule enforcement have been effective (Agarwal and Gupta, 2005; Gibson et. al., 2005).

its users. Knowledge among users (U7) and importance of the resource to its users (U8) are identified features enabling self-organizing of resource users in the framework[14] described to analyse sustainability of socio-ecological resource systems (Ostrom, 2009).

The subterranean network in which the groundwater flows, makes it difficult to ascertain immediate impact of resource extraction, and hence, identify and limit its extent. Accordingly, an opportunity for resource users to coordinate their actions towards more sustainable extraction practices may be created by dissemination of technical knowledge about groundwater extraction that is collected sophistically. Agricultural extension agencies are identified as institutions that are particularly well placed to fill this knowledge gap. Especially, institutions that offer continuous services can not only provide crop advisory, but also disseminate information on ways of manging water balance within the watershed. In this research, knowledge of the resource system is represented by the household's interaction with agricultural extension agencies.

The importance of the resource is represented by the household's crop choices in an agricultural season. Climate vulnerability of the semi-arid regions, encourages farmers to multi-crop; and this crop choice is a measured decision between household's irrigation potential and aspiration of higher agricultural income. Crop choices also determine the incentive to cooperate; a farmer whose crop mix includes more crops for commercial purpose has a higher incentive to cooperate and value resource sustainability in comparison to a farmer cultivating for subsistence (Gibson, 2001).

Under these premises, the specific research question addressed here is: What factors influence households to choose a crop portfolio that is relatively more irrigation demand intensive others? The importance of the resource system is modelled as a dependent variable and interaction with extension agency is treated as an independent variable among other explanatory variables.

The data for this study was collected through an enumerated survey conducted in two neighbouring micro-watersheds located in the semi-arid district of Ahmednagar, Maharashtra, India. Village 2 covers over 1535 hectares and is home to nearly 140 households. Village 3 is

14 Ostrom identifies a multi-level framework for analysing sustainability of Socio-ecological Systems. The Level 1 variables are Social, economic and political setting (S), Resource System (RS), Resource Units (RU), Governance (G) and Users (U). The variables U7 and U8 are Level 2 variables in Users (U).

spread over 910 hectares with 176 households. The survey was conducted during December 2016 – January 2017 in Village 2 and in August 2017 in Village 3[15].

The rest of this paper is organized as follows: Section E1.1 provides a background to the WDP programme in India. Section E1.2 describes the study region, Section E1.3 elaborates on the methodology followed by empirical analysis, Section E1.4 presents the results, and Section E1.5 summarises the inferences drawn from the study.

E1. 1 WDP in India

A watershed or catchment, as defined in the Soil and Land Use Survey of India, is an area such that all the water falling on it drains to a common point. River basin is the principal reference point for WDP planning, and the smallest representative of a catchment is a micro-watershed (Lobo, 2002). Micro-watershed is also the preferred unit of programme planning as it is a size conducive to community based natural resource management (Kerr, 2007). A micro-watershed encompasses an area between 500 hectares to 1000 hectares.

WDP places special focus on dry land and hilly regions, because poverty is typically highest there, due to the dependence of agricultural livelihoods on degraded natural resources (Parthasarathy Committee Report, 2006). Nearly 69%, that is, 228 million hectares of in India is classified as dry land. The key tools used for resource rejuvenation are, land treatment, afforestation and construction of percolation tanks. Most land works are implemented along the ridge lines of the watershed, and percolation tanks are constructed in the valley of a watershed – a ridge to valley approach. The land treatment involves construction of continuous contour trenches, gully plugs and various other structures built to slow down rainfall runoff. This slower runoff is then channelled to percolation tanks. Collected water in these tanks seeps down and raises the ground water-table levels.

Communal participation is critical to successful programme implementation (Kolavalli and Kerr, 2002). Correspondingly, it is also seen that, substantial time and efforts are spent by the project implementing agency in building good rapport with the community (D'Costa and Samuel, 2001). A Village Watershed Development Committee (VWDC) is set up during the inception phase of the project. This committee acts as the point of communication between the villagers and the development agency. It is a registered body with membership typically ranging between 10 and 25. The project implementation norms require VWDC to ensure

[15] Three villages have been studied in this thesis and their numbering has been retained throughout for consistency. The villages studied in this essay happen to be numbered Village 2 and Village 3.

representation of all sections in the community, particularly small holding farmers, women, landless and members of various caste hierarchy in the community (Parthasarathy Committee Report, 2006). Committee members and office bearers are elected/nominated by the villagers. This committee is also responsible for maintenance and monitoring of the watershed post programme implementation period, and is endowed with a maintenance fund.

Communities tend to shoulder nearly 16 to 18% of the total project cost (NABARD, 2016). The contribution can either be in the form of voluntary free labour, referred as Shramdhan or cash contribution. The extension agencies have a preference for Shramdhan, because participation through voluntary free labour encourages 'learning by doing', which then contributes to capacity building that is required for maintenance and monitoring of the watershed structures (Gray and Srinidhi, 2013).

Post successful implementation of WDP, the conjunctive use of ground water along with seasonal rainfall is expected to increase agricultural productivity. Some of the indicators used to measure programme success include: increased availability of drinking and irrigation water, land under cultivation and horticulture, recharge levels of ground water, recharged wells, number of new wells, land under afforestation and decrease in seasonal out-migration for employment.

E1. 2 Study Region

The criteria for selecting watershed communities, were guided by interest in tracing the sustainability of watershed management practices that were followed post WDP implementation. Therefore, age of the watershed was a key parameter. One of the oldest, yet representative of current WDP, were the projects financed under the Indo-German Watershed Development Programme (IGWDP) (NABARD, 2006). Among the initial few projects covered under this programme, two micro watershed communities were chosen to be studied that had successfully implemented this programme. The villages are located in the semi-arid district of Ahmednagar in Maharashtra adjacent to each other on either side of the ridge line. Consequently, they were covered under two independent projects implemented by the same development agency. Projects began in the late 1990s and were completed by early 2000s; thus, the watersheds are nearly two decades old. There is a gap of one year between the project commencements, with Village 2 accepting the project before Village 3.

E1. 3 Methodology and Analysis

Prior to WDP, both drinking water and food were scarce in the study villages. Post WDP, nearly all of the households in Village 2 and 92% in Village 3 cultivated their land. A variety of crops are grown for self-consumption and for commercial purposes. Agriculture being the mainstay, the crop choices aim to minimize risks associated with cultivating in semi-arid conditions and, at the same time, maximize agricultural returns. Irrigation potential of the household influences crop choice decisions, thus crop choices of the households are analysed initially.

Based on the crop choices and their corresponding irrigation requirement, farming households were categorized into groups of highest, medium and the least irrigation demanding farmers. Farmers with higher irrigation demand are more likely to place a greater value on provision for irrigation. Treating crop choice as a categorical, dependent variable, factors that may influence this decision are identified as, agricultural land, income from agriculture allied activities, household labour, financial support and knowledge support provided by agriculture extension agency, and are considered to be explanatory variables. Probabilistic regression is applied to draw statistical inferences.

The data was collected through enumerated household surveys conducted by a team of four people. The survey questions were designed to capture information from the household head. Data on demographic characteristics, land ownership and holding size, land use (crops cultivated), ownership of water assets (privately held or shared) and its form (wells, borewells, farm ponds), annual income from agriculture and allied activities, credit availed for agricultural purposes (formal sources and relatives) and perception on water availability (measured on 3-point scale) were collected. The survey enumerated all households in the watershed villages to account for the nature of distribution of irrigation demand within the watershed that may influence the scope of collective action in the community.

E1 3.1 Crop Choices and Irrigation Availability

The average farm size is 2.23 hectares in Village 2 and 1.99 hectares in Village 3. Small farm holders (land holding less than 2.5 hectares) constitute 45.6% and 56.8% of the total in Villages 2 and 3, respectively. The two main agricultural cycles are the kharif and rabi. The first cycle (kharif) lasts from July to October and the second cycle (rabi), from October to March. Most households in the village are able to cultivate during both agricultural cycles. Of the two cycles, the kharif yield and returns are higher as it is the first cycle post annual seasonal rainfall. The soil is moisture laden helping better crop survival during this season. Most cash crops are grown during kharif and crops for subsistence purposes are typically grown in rabi.

Crop diversification is the dominant cropping strategy and a variety of crops for self-consumption and commercial purpose were grown depending on the irrigation potential of the households. Wells are the primary source of irrigation and their numbers proliferated after WDP programme implementation. There were 131 groundwater extraction access points among the surveyed 127 households in Village 2, and 179 wells among 172 households in Village 3. Some wells have shared ownership, usually between extended members of the same family. Twelve examples of such shared wells were observed in Village 2 and 25 in Village 3. Though the numbers of wells and the number of households are almost equal, they are not uniformly distributed. 32 households in Village 2 and 45 in Village 3 did not own a well. Data on ownership of wells suggests that it is linked to land holding size, with private investments in wells also increasing along with it, as seen in Table E1.1.

Although this data means that 75% of households owned at least one private well, ownership did not ensure that their irrigation requirements are sufficiently met. Only 6% of the farmers in Village 2 reported that their irrigation needs were fully met, and none in Village 3 did. Water availability in the wells depends on the amount of annual rainfall these villages receive. In a year with poor monsoon, village wells and percolation tanks run dry. Consequently, water was imported into the villages by water tankers costing ₹1,67,000 and ₹5,06,000 for villages 2 and 3 respectively, in the 2016-17 agricultural year.

Table E1.1: Ownership of wells across land holding

			Village 2			
Land holding	Land holding size (acres)	n	Wells	B.wells	C.wells	Total
Marginal Farmers	<2.5	28	10	4	3	17
Small Farmers	2.5 to <5	30	16	9	4	29
Semi-medium Farmers	5 to <10	47	34	16	4	54
Medium Farmers	>10	23	19	11	1	31
Total		128	79	40	12	131
			Village 3			
		n	Wells	B.wells	C.wells	Total
Marginal Farmers	<2.5	34	9	4	5	18
Small Farmers	2.5 to 5	62	37	28	11	76
Semi-medium Farmers	5 to 10	49	30	12	6	48
Medium Farmers	>10	23	25	9	3	37
Total		168	101	53	25	179

Data Source: Primary data *B.wells for borewells , C.wells for common wells*

These perceptions of insufficient irrigation reflect shortages in its supply. However, they should also be thought of as increased irrigation demand, resulting from adoption of new cropping patterns following WDP intervention (Calder, 2008). This is an artefact of technological innovation being a process in which subsequent interventions are required to ameliorate the induced water scarcity, due to the higher demand created by the original intervention undertaken to improve water availability. These perceptions thus are indicative of the WDP being successful in improving water supply and livelihoods, and driving higher capabilities and aspirations of the villagers adapting to the new opportunities.

E1 3.2 Crop Choice and Risk Mitigation Strategies

Increasing rainfall variability and the seasonal dependence of the irrigation potential encourage households to adopt risk mitigation strategies. Two farm level risk mitigation strategies are typically seen: (a) Crop diversification and (b) allocation of a smaller proportion of cultivated land for cash crop cultivation.

(a) Crop diversification:

A variety of food crops are grown for self-consumption to ensure a minimal, yet well-balanced basket. Coarse food grains (pearl millets in kharif, wheat and sorghum in rabi) and up to three varieties of pulses are seen to be grown for self-consumption. Onion, tomato, cotton and soybean are the common commercial crops. Legume crops such as groundnut and pulses are grown for both, self-consumption and commercially. Farming households with livestock allocated a share of land for fodder cultivation too.

Notably, not more than 30% of the total land cultivated was allocated for commercial cultivation across all farm size categories in kharif (Table E1.2). Climate risks being co-variant to it, risk minimization strategies across all farming household sizes resemble each other (Dercon, 2002). However, greater diversification among commercial crops is observed with an increase in land holding size, thus enabling the farmers to cover risks better. On an average, a small holding farmer cultivated at least one food crop, whereas a medium farmer cultivated three food crops and at least one cash crop. A few landed households have been able to include pomegranate in their portfolio, thus generating a horticultural produce. In the case of Village 3, relatively larger share of land was allocated to fodder cultivation as livestock income was widely integrated into their income portfolio.

Table E1.2: Distribution of land among food, cash and fodder crops in Villages 2 and 3 – Kharif

Category	Land holding size (acres)	Number of households	Total Land holding (acres)	% of total land holding Food crop	Cash crop	Fodder
Village 2						
Marginal Farmers	< 2.5	28	40.2	80%	20%	0.00%
Small Farmers	2.5 to 5	30	86.15	78%	22%	0.00%
Semi-medium Farmers	5 to 10	46	208.87	62%	30%	4.20%
Medium Farmers	> 10	23	177.75	70%	24%	6.00%
Village 3						
Marginal Farmers	< 2.5	34	47.35	72%	18%	0.73%
Small Farmers	2.5 to 5	61	166.9	62%	21%	12.00%
Semi-medium Farmers	5 to 10	49	179.48	65%	18%	14.00%
Medium Farmers	> 10	23	175.9	47%	29%	18.00%

Data Source: Primary data 1 Acre = 0.40 hectares

Farmers prefer to grow food for self-consumption under rain-fed conditions and utilise irrigation for their commercial crops. However, the likelihood of growing both cash and food crops under irrigated conditions was observed to improve with increase in the size of land holding. In Village 2, the proportion of land under irrigated food crop cultivation increases from 15% for marginal farmers to 50% for medium farmers; whereas for cash crops, it increases from 74% to 100%. Similarly, in Village 3, the proportion of land under irrigated food crop cultivation increases from 38% for marginal farmers to 52% for medium farmers; whereas for cash crops, it increases from 55% to 85%. The difference in irrigation allocation between the villages is influenced by the extent of livestock adoption and the share of rain fed dry land crops in the crop portfolio.

Crop insurance was purchased for cash crops, but households rarely reported to have benefitted. The claims were usually rejected because crop loss experienced due to poor rainfall at the village level rarely coincided with the identified weather risk affected regions by the insurance companies. Index based insurance is an improvement on crop-based insurance scheme, however its effectiveness is unsatisfactory (Binswanger and Hans, 2012). Nonetheless, the subscription rates remain high because crop insurance schemes are tied together with agricultural loans by credit providing institutions.

(b) Income diversification

In addition to farm level risk mitigation strategies for securing livelihoods, households also engaged in various forms of income diversification. The WDP implementation agency emphasised the possibility and merit of incorporating livestock into the income portfolio of the households. Livestock income constituted 35% and 51% of the total annual agriculture and allied activities-based income in Village 2 and Village 3 respectively. The higher adoption of livestock in Village 3 appears to be motivated by the presence of a milk collection centre set up by an accredited milk cooperative within the village.

A less desirable choice of supplementing agriculture income is farm labour wages. As these villages pre-dominantly cultivate food crop for self-consumption, the opportunity of farm labour employment within the village is limited. Therefore, households reporting labour income are those whose members have typically migrated out, seeking wage labour opportunities during winter (rabi) and summer seasons. This is a less desirable choice for households, as seasonal migration affects quality of their family life. In most cases, the male members in the household migrated leaving women, children and older members in charge of subsistence cultivation in the village. Labour income was earned by 21% of the households in Village 2 and 43% in Village 3.

A third alternative is formal employment in non-agricultural sector, and households undertaking this opportunity had higher educational levels than others. They were also fewer in numbers. The data collected on household income accounted for income accruing from (1) sale of agricultural produce (2) livestock income in the form of sale of milk (3) wages earned from farm labour and (4) wages from non-farm formal employment.

The nature of strategies for securing livelihood and mitigating risk shows that the effect of crop diversification cannot be separated from that of income diversification and vice versa (Dercon, 1996). For instance, a household that diversifies income through livestock, allocated a part of their land to fodder cultivation, whereas, a household that earned income through wage labour, mostly allocated their land only under subsistence cultivation. Nevertheless, crop choices they make are crucial in determining their income from each agricultural cycle.

E1.3.3 Empirical Model

Smaller land holding, and further smaller proportion of land under irrigated cultivation, become the primary hurdle in generating higher income from a small patch of land. As irrigation potential of the household is a crucial enabler here, this empirical analysis attempts to understand the factors motivating the households to choose more (or relatively less) water demanding commercial crops in their portfolio. Households aspire to include irrigated crops for substantial improvement in income. We posit that this potential of earning higher income by including a water consumptive crop motivates the farmers to accord a higher value to irrigation.

Irrigation demand of households are inferred from the crop choice made in relation to planting in the kharif season of 2017. The choices were disaggregated into three groups (1) Group1: Households that grew only coarse food grains and pulses – pearl millets and legumes (2) Group2: Households that grew at least one low irrigation consumptive, dryland commercial crop such as onion and soybean) (3) Group3: Households that grew at least one high value, high water consumptive dry land crop of tomato, cotton or pomegranate.

In Village 2, 18% of the total population belonged to Group1, 50% to Group2 and 32% to Group3. Whereas in Village 3, 23% of the total population belonged to Group1, 59% to Group2 and 18% to Group3.

Among the three categories, as Group1 farmers cultivate crops for subsistence under rain-fed condition, their irrigation demand is very low. Also, concerns underlying crops chosen for subsistence are likely to be distinct from that for commercial farming. Therefore, in the analysis of irrigation demand of farmers, this category of households was dropped. This left nearly 82% of farming households in Village 2 and 77% in Village 3 engaged with commercial farming to be compared. The average household income of Group 3 is nearly 1.87 times more than that of Group 2 in Village 2, and 2.7 times for Village 3.

Probabilistic regression model is chosen for empirical analysis. This technique was chosen because it allows a robust, yet simple procedure to check for heteroscedasticity arising from either large variance in cross sectional data or model mis-specification. The estimates were performed independently for the two villages as they belong to two different WDP.

$$\textit{Crop choice household} = \beta_0 + \beta_1.\textit{Tirrland} - \beta_2.\textit{LivestockY} + \beta_3.\textit{Hhlab} + \beta_4.\textit{Credit} + \beta_5.\textit{Extension} + \varepsilon$$

$\varepsilon \sim N(0, \sigma 2)$ where,

Crop choice = binary variable,

0 = Crop choice belonging to Group2

1= Crop choice belonging to Group3

Tirrland = Total land under irrigated cultivation in kharif

LivestockY = Share of livestock income to agriculture and agriculture allied income

Hhlab = Number of members in the household contributing to agricultural labour

Credit = Credit availed from formal lending organisations for agricultural purposes in the last three years

Extension = Perception on effectiveness of agricultural advisory provided by an extension agency. A five-point scale was used with 1= least useful and 5 = extremely useful, 0 = for when the service is not subscribed

Table E1.3: Descriptive statistics of explanatory variables

Village 2 (Commercial farmers - 98 households)					
	Units	Mean	S.D.	Min.	Max.
Irrigated land	acres	5.26	4.64	0	24
Livestock share	%	37.14	36.78	0	100
Household labour	person	2 or 3	1	0	6
Credit	₹	92,938.78	156,763.80	0	670,000
Interaction with agricultural extension	scale	1.04	1.47	0	4
Village 3 (Commercial farmers -128 households)					
	Units	Mean	S.D.	Min.	Max.
Irrigated land	acres	5.11	5.11	0	26
Livestock share	%	50.96	39	0	75
Household labour	person	2 or 3	1	0	6
Credit	₹	78,234.38	133,823.50	0	600,000
Interaction with agricultural extension	scale	1.00	1.59	0	4

Data Source: Primary data

Most crop choice decision models include personal characteristics of the decision maker such as education, age and gender. Higher levels of education, lower age and being a male farmer is likely to positively influence adoption of risky high value crop; however, these variables were not included in the model. The, completion of secondary schooling (10 years or 12 years of schooling) is more common among household heads less than 40 years of age, because improvement in schooling infrastructure and accessibility to formal schooling is a more recent provision. As years of schooling pertain only to non-vocational training, so it has been argued that the engagement of a household with agricultural extension agencies is more likely to influence crop choice than formal years of schooling. In case of gender, farm land in nearly all cases is owned by the male head of the household. Households reported women as their head, only for widows with minor children.

Including age in the model, resulted in estimation error due to heteroscedasticity, so age squared variable was explored for a non-linear relation. But neither age nor age squared variable produced a statistically significant result, hence, age was dropped from the model. This heteroscedasticity is potentially because of the unclear relation between the age of the head of the household and the number of people in the household. The collected data suggests, when the share of agriculture and (or) livestock income in the livelihood portfolio is higher, more family members live together with the increasing age of the household head. On the contrary, when the share of agriculture and allied income is less, the household size was relatively small, irrespective of the age of the household head. Descriptive statistics for the explanatory variables are shown in Table E1.3.

Total irrigated land: An increase in the total irrigated land is likely to encourage farmers to include a high value water consumptive commercial crop in their portfolio (Matuschke and Qaim., 2009). High value crop is a high return – higher risk livelihood strategy of a farming household.

Livestock income: An increase in livestock income is likely to discourage a farmer from adoption of high value water consumptive crop. When an opportunity exists for crop diversification supported by an opportunity for crop specialization, farming households are less likely to diversify to livestock income generation (Walker and Ryan, 1990). Households that included more livestock in their income portfolio, allocated a larger share of land under fodder cultivation, and notably under irrigated conditions.

Household Labour: Every additional household member contributing to farm labour is likely to positively influence its crop adoption decisions (Crost, et. al., 2007). Nearly 80% of the cultivable land in the study villages is allocated to subsistence farming, therefore hiring labour is less profitable. Also, availability of agricultural labour itself is another challenge, and farm labour requirements are often met by members of the households. Greater household labour contribution, leading to better division of labour provides a better opportunity to utilise that towards growing high value crops.

Credit: An increase in credit availability is likely to have a positive influence on crop choice (Matuschke and Qaim, 2009). Commercial crop choice typically creates a requirement for better irrigation. Wells, deepening of wells, bore wells, construction of farm ponds or investing in micro-drip irrigation systems are some of the methods for making this investment.

Agricultural Extension Services: An increased interaction with crop extension services is likely to encourage the adoption of high value commercial crops (Matuschke and Qaim, 2009). On the contrary, adoption of high value crops may also lead to an increased interaction with those agricultural extension agencies. In case of the WDP project villages, as crops demanding higher irrigation were introduced in the village by the project implementation agency as a means of increasing agriculture income, the variable has been treated as an explanatory variable. The primary provider of crop extension services in the country are the Krishi Vigyan Kendras (KVKs). Apart from KVKs, private agencies and certain non-government organisations also provide these services. Skill-building training programmes for farmers, agro-advisories, and dissemination of weather information are some of the key services provided. The most popular form of interaction between farmers and extension services is through subscription to agro-advisory services. Advice is sent as text message, in regional languages to their mobile phones. All households in the surveyed villages owned a mobile phone. Data also suggests that farmers working in close collaboration with extension services are more likely to invest in water use efficiency measures such as drip irrigation systems, particularly for high value commercial crops.

E1.4 Results and Discussions

The model specification is highly significant statistically (probability < 0.00) for both the villages. The likelihood ratios (LR Chi2) are 32.15 and 33.15 respectively.

Table E1.4: Parameter estimates of probit model for Village 2 and Village 3

Probit Estimates				
Explanatory variables	**Village 2**		**Village 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Irrigated land	0.0592	0.098***	0.0006	0.981
Livestock share	0.0005	0.896	-0.0143	0.000*
Household labour	0.1997	0.085***	0.301	0.007*
Credit	2.94E-06	0.006*	2.28E-06	0.021*
Agricultural extension	0.322	0.001*	0.1893	0.025*
Constant	1.8057	0.000*	1.406	0.000*
Base outcome	Dryland crop		Dryland crop	
LR chi2 (4)	32.15		33.15	
Prob > chi2	0.000*		0.000*	
Pseudo R2	0.2457		0.2376	
Marginal Effects				
Explanatory Variables	**Village 2**		**Village 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Irrigated land	0.0223	0.098***	0.0001	0.9819
Livestock share	0.0002	0.896	-0.0036	0.000*
Members	0.0753	0.085	0.076	0.008*
Credit	1.11E-07	0.007*	5.80E-07	0.020*
Extension	0.1215	0.001*	0.048	0.027*

*Significance: * at 1%, ** at 5% and *** at 10%*

The Probit estimates suggest that an increase in irrigated land is more likely to encourage including a Water Consumptive Commercial Crop (WCCC) in the household crop portfolio in Village 2 (Table E1.4). The marginal effects estimates demonstrate an increase in the probability of adopting high value crops by 2% with every additional acre under irrigation (Table E1.4). This low increase in the rate of adoption can be ascribed to the dependence of well water availability on seasonal annual rainfall. In Village 3, this variable was found to be statistically insignificant.

An increase in the share of livestock income was expected to negatively influence adoption of WCCC. In Village 3, where adoption of livestock is relatively more widespread, this relation holds true (Table E1.4). A percentage increase in the share of livestock income to total agricultural income reduces the probability of adopting water consumptive commercial cropping by 0.3% (Table E1.4, marginal effects). Similar inference could not be made for Village 2 as this variable was statistically insignificant.

An increase in household labour is likely to positively influence WCCC adoption in both the villages (Table E1.4). With the addition of labour contribution of every additional household member, the probability of WCCC adoption increases by 7.5% and 7.6% in Villages 2 and 3 respectively (Table E1.4, marginal effects).

An increase in availability of agricultural credit is more likely to influence crop choice in favour of a WCCC (Table E1.4). A ₹100,000 loan increases the probability of crop adoption by 11 % in Village 2 and 5.8 % in Village 3 (Table E1.4, marginal effects).

Greater interaction with the extension agency is found to encourage adoption of WCCC. In case of villages 2 and 3, it increases the probability of crop adoption by 13% and 5% respectively (Table E1.4, marginal effects). This result coupled with the observation that the extension agency could potentially influence adoption of water use efficiency has implications for resource use. It also highlights the potential that agricultural extension agencies possess for improving the community level knowledge about safeguarding sustainability of groundwater use.

The WDP projects ensure better availability of water, the most crucial resource for farming in the semi-arid regions of the country, whilst providing drinking water. Availability of irrigation consequently raises agricultural expectations of households. However, despite subjecting less than 30% of the total cultivated land to commercial cultivation, the irrigation requirements are not satisfactorily met. Achieving a balance between aspiration of higher agricultural income and limited availability of the vital resource of ground water is a challenging proposition.

Emphasis on diversification into agriculture allied actives is necessary not only to reduce the dependence on commercial agriculture, but also to cover agricultural income risks (Reddy et al, 2004). Along with a programme push for adoption of livestock, support for assured access to market for their products is necessary to reduce groundwater dependence. In Village 3, where a milk collection centre was set up; it encouraged more farmers to invest in milch cows. As a result, only 18% of the farmers pursued cultivation of WCCC. In the absence of such alternative markets, income diversification is limited to crop diversification opportunities resulting in more farmers attempting for successful adoption of horticultural crops. This tendency is observed in the case of Village 2, where 32% of the farmers belonged to the category of farmers with higher water consumption demand. Notably, livestock adoption also remained limited only to the category of relatively well-endowed irrigated farmers in Village 2.

The results indicate that, in addition to developing a market for agriculture allied products, engagement with agriculture extension agencies should be highly encouraged. Engagement with such institutions not only contributes to improvement of agricultural productivity, but they are also very effective in communicating the use value of water. Prior to WDP, irrigation by flooding was the familiar, and hence popular method of irrigation. Intervention agencies played a key role in encouraging irrigation by drip technique and sprinklers, particularly for horticultural crops, emphasising the efficient use of water. In Village 3, where the extension services continued to engage with the community post WDP, the adoption rate of efficient irrigation methods (drip and sprinkler sets) was higher, and was even used for cultivation of subsistence crops.

E1.4.1 Local Knowledge and Collective Action

Monitoring of common pool resource such as the groundwater-based irrigation system is particularly challenging because of the elusive nature of the resource itself. As the resource flows are sub-surface, the impact of groundwater extraction by users are revealed only at a later point in time. Measuring immediate or short-term impacts need sophisticated methods of resource monitoring. Agricultural extension institutions possessing such knowledge have an advantage in supporting the community in this regard. These agencies can further assist the community to manage their irrigation demand with timely crop advisory.

Location specific advisory and monitoring is certainly effective, but charting such specific plans requires higher resource investment in the community by these institutions. For example, extension agencies can set up weather monitoring stations, scientifically monitor groundwater tables, and visit the community more frequently. This culminates in development of village-community specific, livelihood strategies. Such investments and benefits for communities are dependent on establishing partnership between facilitating institutions.

In an interview conducted, a senior officer of such an institution said “The demand for the development intervention should arise from the community”. The reference to ‘demand from the village’ signals a level of collective demand sufficient enough to assure the extension agency to invest in the community. Results from the empirical analysis (Tables E1.4) suggest that resource users with higher irrigation demand in both the villages were in more regular contact with the extension agency. However, currently, only Village 3 that has been able to attract specific attention of the extension agency, despite high irrigation insufficiency in both villages. Furthermore, the nature of engagement of the villages with the extension services, revealed that, farmers engagement with the agricultural extension agencies was primarily only for agriculture advice in Village 2. Secondly, farmers here choose multiple extension agencies as their service providers.

In case of Village 3, along with the recognized need to seek support from an extension agency, farming households were able to arrive at a common consensus to identify a particular extension agency. In an interview, the leader of the village local government said, "Post WDP, the farmers were exhilarated with increased availability of irrigation and took to cultivating highly water consumptive crops such as sugarcane. In less than five years, our wells started to dry out. We realized that our water should be used more judiciously. We decided to contact agricultural extension agency for help". Village 3 successfully convinced the extension agency to commission another project pertaining to water use efficiency and crop management in the village. The project began implementation this new project in January 2018.

Qualitative evidence indicates that farmers have the ability to use evidence from water availability to further their understanding of requirements for sustainability of a WDP. This is facilitated further by actively seeking assistance from the extension service institution. Furthermore, the ability to use this knowledge collectively was crucial for motivating the farmers to actively contact the extension agencies to further increase crop diversification and improve their income earning capacity. It appears that the 'learning by doing' also built resilience in the community to use the knowledge more iteratively.

E1.4.2 Village Cohesion and the Ability to Work Together

As the age, location and the size of watersheds are similar between the two villages, difference in the ability to act collectively may arise from village specific social factors. To identify, any such differences between the villages, we compared village specific characteristics that influence formation of social capital in the society.

(a) Caste heterogeneity

In communities with higher social capital, trust and cooperation are achieved with relatively less effort, prompting collective action required for community based natural resource management. Members of the same caste are more likely to interact and trust each other (Bouma et.al., 2008; Pretty, 2003). To understand the status of caste heterogeneity in the study villages, a comparison between their indices of caste heterogeneity was made. Heterogeneity in caste was computed based on the method applied by Bhim and Lovett, 2006.

$$Index\ of\ caste\ heterogeniety\ = 1 - \sum_{i=1}^{n}(P_i)^2$$

where, P_i is the proportion of total households in the i^{th} caste in a village. A value of the index closer to 0 indicates caste homogeneity in the village, and value closer to 1 indicates caste heterogeneity.

Student t test was applied on the index to deduce any significant difference in the average caste. The result suggests a significant difference (t value of 9.410 significant at 1%) in the caste index. Village 3 was significantly heterogenous in its caste distribution in comparison to Village 2. Additionally, the caste identified as the traditional agricultural caste in Maharashtra - the Marathas – constituted the majority here.

(b) Experience of working together

A well-functioning milk cooperative is operational in Village 3. Many households own Jersey milch cows, and they sell their produce to the milk collection centre located in the village. This actively could indicate their trust in the society, encouraging them to take up collective action. Though there are no established (registered) farmers' cooperatives in the village, when the survey was conducted, they expressed strong willingness to set one up, in order to facilitate marketing of their produce. In the case of Village 2, there was no evidence of any form of farmers' or a milk cooperative. In response to a question in the survey ascertaining the preference for membership in various forms of cooperatives (farmers' cooperative, cooperative for marketing, financial cooperative or none), 42% of farmers expressed that they did not perceive a cooperative to be useful for making livelihood choices, nor did they desire to become members of any such institution.

The existence of caste heterogeneity and lack of experience in working together may have delayed formation of social capital in Village 2, but, it does not appear to have been an unsurmountable problem as the villagers did work together and also contributed voluntary labour for WDP implementation. Village 2 was also the leader in welcoming WDP intervention when the programme was newly introduced.

E1.5 Conclusion

WDP is a crucial programme for poverty reduction and livelihood improvement of farming households in the semi-arid regions of India. Afforestation and water harvesting efforts together check land resource degradation and provide an opportunity to increase water availability and agricultural income. Participatory planning is identified as the key to successful programme implementation. The focus of this research is on identifying factors that aid sustainable management of micro-watershed after programme implementation. Effective and sustained management of watershed by the community can result in consistent livelihood gains.

The elusive nature of groundwater resources results in impacts that are not easily and immediately perceivable to resource users. Farmers acting in their individual interest may extract water quicker than the rate at which rainfall is harvested and groundwater tables are recharged within the watershed, leading to resource depletion. Water resource scarce semi-arid regions are more prone to such risks. Support for monitoring from organisations with the requisite knowledge advantage such as agricultural extension agencies, is shown to aid the community in this regard. These institutions are capable of disseminating crucial information regarding resource use and its impact on sustainability of the resource. The results of this study suggest, farmers who demanded more water from the watershed, were also the ones who engaged more actively with agricultural extension agency. Further, these farmers also adapted irrigation practices to bolster efficiency. The evidence from this research aligns with the thought that resource users who are more dependent on the resource are the ones who value its sustainability (Gibson, 2001). Increased collective awareness among users about the resource system is likely to revive collective action (Ostrom, 2009); in the same manner that collective action by the community was mobilized for the implementation of WDP (D'Costa and Samuel, 2001).

Ability to act collectively may enable communities to engage in an active partnership with agricultural extension agencies. To improve the overall effectiveness of the development intervention, allocation of more resources by extension services in the community, post WDP is essential. Importantly, well-managed watershed improves average benefits accruing to all in the community. WDP implementation agencies have an advantage over other third-party extension agencies, therefore continuation of engagement (link) with the communities post WDP is beneficial.

Lastly, reducing dependence on groundwater is necessary, therefore agriculture allied activities should be encouraged. Importantly, adoption of new livelihood strategies requires provision of ease of market accessibility too – a crucial trigger in encouraging households to adopt new strategies.

Essay 2

Social Capital and Collective Action: Sustainable Management of Micro-watersheds in Semi-arid India

Abstract:

Implementation of Watershed Development Programme (WDP) increases the overall irrigation availability in the micro-watershed. Increased availability of irrigation encourages farmers to pursue higher agricultural ambitions and consequently demand more irrigation. To match increased irrigation demand farmers may choose to invest in further groundwater extraction, risking resource depletion. Alternatively, encouraging farmers to invest in farm level water harvesting measure to fulfil, at least a share of the increased demand; may contribute to groundwater resource health. Since 2016, the state government of Maharashtra has been promoting adoption of farm level rain water harvesting structures. This research, evaluates the role of importance of the resource (U8) and social capital (U6) in the community – two features identified in Ostrom's sustainability of Socio Ecological System (SES) framework. Data was collected from two micro-water village communities located in two different rainfall zones within regions identified as practicing dryland agriculture. The research finds, collective action and resource use norms emerge when agricultural income of farming households are high in the community. Social capital in the community plays a significant role in enabling more households in the community to invest in water harvesting, thereby facilitating adherence to resource use norms banning over extraction of groundwater resources.

Keywords: Micro-watershed, farm ponds, social network analysis, social capital, agricultural extension, collective action, semi-arid India

E 2. Introduction

Watershed Development Programme (WDP) is one of the primary development strategies identified to secure and increase agricultural production through adoption of soil and water conservation measures. The semi-arid regions of the country receive special focus under this rural development programme as the agricultural livelihoods are poor in these regions (Parthasarathy report, 2006). Successful implementation of such projects enables village communities to harvest annual seasonal rainfall and retain it as groundwater. Farmers access this groundwater through privately and individually owned wells. Access to irrigation encourages agricultural aspiration resulting in increased demand for irrigation (Bouma and Scott, 2006). To meet the increased and evolving irrigation requirements, farming households may choose to further invest in groundwater extraction, overlooking its public good nature. In the interest of resource use sustainability and thereby livelihood sustainability, this research attempts to analyse pathways through which resource users may be encouraged to invest in individual water harvesting measures such that at least a share of the increasing demand may be met without groundwater extraction.

Since 2010, various state governments in the country have been encouraging construction of farm ponds to harvest annual seasonal rainfall at the farm level (Reddy et. al., 2012). In the state of Maharashtra where nearly 70-80% of the cultivated land practices dryland farming, the state government has announced construction of farm ponds as a necessary measure to build resilience against climate variability and drought proofing agriculture. While adoption of this method has merit, in the absence of effective groundwater monitoring at the community level, these farm ponds may reduce to being groundwater storage structures exacerbating depletion of groundwater tables, particularly in the semi-arid regions (Kale, 2017). Management of groundwater is a challenge due to the complexities of managing socio-ecological resource systems. However, identifying pathways to achieve effective local governance is desirable as it safeguards sustainability of resources and improves stability in agricultural livelihoods across the watershed community.

This research contributes to the literature of sustainable management of common pool resource systems by highlighting the factors that influence self-organization of resource users to achieve coordination in resource use in groundwater-based irrigation systems. Collective action in the community reflects in enforcement of water use norms, which then will shape an individual's investment preference in water assets. Specific to the context, in communities that value sustainability of groundwater, farmers are more likely to additionally invest in sources of irrigation that will relive increased dependence on groundwater for irrigation. While such investments have private benefits accruing from diversified sources of irrigation; they also contribute to public benefit by reducing individual dependence on the common - groundwater resources. Thus, the specific research question pursued is, what are the factors that influence farmers decision to invest in farm ponds? This research focuses on the role of *importance of the resource* (U8) and *social capital* (U6) in encouraging collective action in micro-watershed communities; based on Ostrom's framework to analyse sustainability of socio-ecological systems.

The importance of the resource is represented by agricultural income of households. Higher commercial value of the crops cultivated will encourage household decision to invest in water harvesting efforts; as households are more likely to value sustainability of resource when their resource dependence is high (Gibson, 2001). Social capital in the community and its influence on household decision making to invest in water harvesting efforts is represented by household's *betweenness score* computed based on social network analysis. Betweenness score is representative of both social support and knowledge support among resource users in the community (Bodin & Crona,2008). Higher level of social capital either encourages reciprocation in resource use behaviour (Wade, 1998; Pretty, 2003) or (and) keeps the cost of resource monitoring at lower levels (Gibson et. al., 2005).

In addition to social capital within the community, the importance of social networks between watershed village communities and institutions such as agricultural extension agencies in building social capital within the community is highlighted. Agricultural extension agencies are capable of supplying and updating knowledge required for management of complex socio-ecological resource systems, and the knowledge enables communities to value resources dearly (Samuel, 2007).

Findings of this research are relevant to identify pathways of improving management of micro-watershed post project implementation. Poor maintenance of micro-watersheds post programme implementation is a concern (Glendenning et al., 2012). It is also relevant to current state government policies promoting scaling-up of farm pond adoption as an effective measure to drought proof rain fed agriculture.

The data for this research has been collected from two micro-watershed village communities located in the semi-arid district of Jalna and Ahmednagar in the state of

Maharashtra. Data was enumerated from all inhabitants though a household survey; a total of 476 households. The choice of the site was based on the, age of the micro-watersheds; and the level of annual rainfall the region received. WDP in the study villages were implemented in the early 2000s; about 15 years of gap after the programme implementation allows the opportunity to study how resource use and resource governance have evolved in the community. Micro-watersheds located in different regions were chosen to understand the limitations that natural resource may cause on livelihood strategies and ultimately on collective action efforts in the community.

The rest of this paper is organized as follows: Section E2.1 introduces the concept of farm ponds and also discusses their importance for dryland agriculture in the semi-arid regions of the country, Section E2.2 provides details of the study region, Section E2.3 describes the study variables and explains the functional form, Section E2.4 presents results and discussion, and Section E2.5 summarizes the inferences drawn from the study.

E2.1 Farm Ponds

Farm ponds are dug-out structures of recommended dimensions placed at the lowest position in a farmland such that the annual seasonal run off can be channelled and stored in these ponds for use at a later time. These structures are designed to collect the maximum rainfall run-off in a farm land and not constructed to enable recharge of groundwater (Reddy et. al., 2012). In a region that receives annual average rainfall between 500mm to 750mm, farm pond with a capacity of 250 m^3 to 500 m^3 can be constructed.

Agricultural performance of semi-arid region practicing dryland farming is heavily dependent on the annual seasonal rainfall it receives in the month of June and July. Nearly 80% of the annual precipitation occurs during these months. Farm ponds aim to harvest this annual rainfall and store them for fulfilling protective irrigation requirements at a later point in the agricultural cycle[16]. In other words, they help in curtailing dip in agricultural productivity caused due to moisture stress that may occur because of dry spells between two subsequent monsoon showers or if the monsoon withdraws earlier than regular season cycles. The instance of such occurrences has increased over the past (o' Brien et. al., 2004; Rao et. al., 2013a; Rao

[16] Farm ponds are not designed to encourage percolation of water and improve the overall water table levels in a micro-watershed; they are designed for the primary purpose of water storage.

et. al., 2016b). As a result, most state governments in the country provide subsidies to farmers to encourage adoption of farm ponds as a measure to achieve climate resilience.

Figure E2.1: Excavated dug out farm pond

Figure E2.2: Excavated dug out farm pond with synthetic lining

A farm pond in the standard measurement of 10m*10m*3m can harvest up to 250 to 500m3 of rainfall, in regions receiving annual rainfall between 500mm to 750 mm (Reddy., et. al., 2012). The preliminary design of farm ponds did not include any form of lining to the pond, however it has evolved to include a synthetic lining or other alternative lining material to improve efficiency in storage (Figure E2.1 and E2.2).

E2.2 Study Region

The state of Maharashtra has a rich background in irrigation management; both formal irrigation through canals[17] and watershed development. Nearly 80% of the 17 million hectares of total cultivated land in Maharashtra is not irrigated, yet it occupies a second place in sugarcane production in the country enabled by government investments in canal irrigation system. In sharp contrast are, the successful cases of community led micro-watershed experiences such as Ralegan Sidhi, Hivre Bazaar grabbing the imagination of policy makers on de-centralized irrigation management. One of the earlier systems of self-organized local water governance, the Pani-Panchayats[18] also belong to this state. Further, the first generation of micro-watershed development programme, namely the Indo-German Watershed

[17] Investments in canal irrigation has been highest by the state of Maharashtra and it occupies second place in sugarcane production in the country.
[18] The system of Pani-Panchayat emerged referees to a specific model of integrated micro-watershed where farmers organized themselves into groups agreeing to follow principles of water sharing. This system emerged in the background of droughts of 1972-73.

Development Project (IGWDP) was first implemented in this state. The practices and protocols followed by this project have been influential in design of current practices and protocols of national guidelines for WDP (Parthasarathy Committee Report, 2006).

The first-generation projects under IGWDP was implemented during late 1990s-early 2000s.Being one of the earlier states to adopt WDP, provides the opportunity to study communities experience in local resource management; particularly in the context of managing the increasing irrigation demand following the WDP implementation. Effective local governance post-WDP is likely to reflect on the state groundwater use in the community.

The state is also of particular interest to the study, because of the relatively new initiative of the government in drought proofing rainfed agriculture regions. Since 2016, the state has initiated a policy to encourage rainwater harvesting at the farm level, namely, *'Magel Tyala Shet-Tale'* (translation: One who demands, will get a farm pond). The government aims to construct at least 52,000 farm ponds in the identified drought prone regions of the state. As per the scheme, a dry land farmer may avail up to 75% of the total cost involved in construction of a farm pond. Quite predictably, the scheme is over-subscribed. Similar projects are also funded by World Bank, namely, Maharashtra Project on Climate Resilient Agriculture. The project is operational since February of 2018 and focusses on 14 drought prone districts of the state.

Though the primary criterion for choice of villages is the average annual rainfall they receive, their choice provides an opportunity to understand how an earlier programme on community-based water harvesting interacts with a current policy of farm level harvesting. Notably, Village 1 provides evidence of early adoption of farm ponds to augment irrigation capacity following WDP as a measure to manage increasing irrigation requirement with a clear intent to reduce dependence on groundwater resources. The first farm pond in the village dates to the year 2001; immediately following WDP implementation. In the case of Village 2, farm pond adoption is motivated by government's recent initiative.

The study villages belong to two rainfall zones classified under dryland agriculture. Village 1, located in the district of Jalna receives an average rainfall 720 mm and Village 2, located in district of Ahmednagar, receives about 420 mm It is the average annual rainfall that determines the prospects of successful farm level water harvesting (Reddy et. al., 2012).

E2.3 Analysis

The IGWDP were implemented in these villages between late 1990s and early 2000s, by two different project implementation agencies. Post the programme implementation, land under cultivation, land under irrigated cultivation and horticulture increased and the expected outcome indicating success. Matching the growing irrigation demand with water harvesting capacity of watershed is a challenge. Despite awareness regarding interconnectedness of groundwater resources, farmers are more likely to act in individual interest, given their private access to it. In the absence of collective action needed for management of resources post programme implementation (second-order collective action), sustained livelihood benefits are less likely to occur.

This research examines the long-term livelihood benefits of WDP, a well-designed programme targeting fundamental concerns such as resource rejuvenation for livelihood enhancement, in two different rainfall zone identified within semi-arid dryland agriculture. Analysis begins with comparative analysis of crop choices in two micro-watershed communities, followed by investigation of its links to irrigation investment, finally evaluating the association between irrigation investment, commercial returns and social capital.

Nearly, 350 households reside in Village 1 of which 322 households are landed farmers. Similarly, 126 households reside in Village 2, and are all landed farmers. The data has been collected through household survey from all the households in the community. As social capital in the community is one of the key explanatory variables studied, social network (links/acquaintance) among all the members of the community was captured. Survey was conducted by a team of 6 data enumerators. The primary respondent of the survey is the head of the household.

E2.3.1 Crop Choice

Agriculture is the primary occupation in both the villages. Of the two agricultural cycles of *kharif* (cycle lasting from July to October) and *rabi* (from October to March), farmers prefer to cultivate commercial crops in kharif and food crops for self-consumption in rabi. The reduced risk of irrigation insufficiency during kharif it being the agricultural cycle following immediately after annual monsoon, assures farmers to uptake commercial farming during this cycle. Additionally, farmers depend on crop diversification for climate risk minimization.

Table E2.1: Distribution of land among food, cash and fodder crops in Village 1 and 2 – Kharif

Category	Land holding size (acres)	Number of households	Total Land holding (acres)	% of total land holding		
				Food crop	Cash crop	Fodder
Village 1						
Marginal Farmers	< 2.5	82 (24%)	132.95	16%	84%	0%
Small Farmers	2.5 to 5	106(32%)	360.25	15%	85%	0%
Semi-medium Farmers	5 to 10	111(33%)	738.25	7%	93%	0%
Medium Farmers	> 10	33(10%)	620	3.5%	97%	0%
Village 2						
Marginal Farmers	< 2.5	28(22%)	40.2	80%	20%	0%
Small Farmers	2.5 to 5	30(23%)	86.15	78%	22%	0%
Semi-medium Farmers	5 to 10	46(36%)	208.87	62%	30%	4.2%
Medium Farmers	> 10	23(18%)	177.75	70%	24%	6%

Data Source: Primary data *1 Acre = 0.40 hectares*

Cotton and onion are the primary cash crops grown in Village 1 and 2 respectively; in addition, soybean and lentils (*toor dal*) are also popular commercial crops cultivated in the villages. In Village 1, across differentiated land holding size, on an average nearly 90% of the total cultivated land in kharif cultivation is allocated to commercial crop and the remaining 10% to food crop cultivation. In Village 2, 30% of the land is allocated to commercial cropping, while 70% to food crop cultivation (Table E2.1).

Table E2.2: Distribution of Horticulture Adoption (in %)

Category	Land holding (acres)	Share of horticultural farmers	
		Village 1	**Village 2**
Marginal farmers	< 2.5 acres	36%	10%
Small farmers	2.5 to 5	60%	27%
Semi-medium farmers	5 to 10	76%	28%
Medium farmers	> 10	91%	43%
Total number of horticulture farmers		208 (62%)	34 (27%)

Data source: Primary data

In addition to seasonal commercial crops, horticultural crops are also cultivated; grapevine in Village 1, and pomegranate and tomato (a seasonal crop, but cultivated under drip irrigated conditions like grapevine and pomegranate) in Village 2. Increased land under commercial cultivation and adoption of horticulture are identified income enhancing strategies in the watershed villages; and they are also indicators to measure impact of WDP. Consistent with the difference in annual average rainfall levels between the villages, horticultural crop adoption is significantly more successful in Village 1 than in Village 2. Nearly two-third of farmers took up horticulture in Village 1, while less than one-third of households were able to do so in Village 2 (Table E2.2). Limited by the poor potential for horticulture adoption, livestock adoption was also recommended for Village 2; however, livestock adoption also remained limited to landed farmers.

E2.3.2 Private Investments in Irrigation Assets

Post WDP, agricultural aspirations in the community increased, driven by the newly gained access to irrigation through wells. Consequently, changes in crop choice and cropping pattern altered water asset ownership portfolio of households. Farmers invested in a portfolio of irrigation assets i.e. ownership of multiple wells, borewells, well deepening, and farm ponds. Private investment provisioning being the means to gain access to irrigation further encouraged farmers to invest in water assets to match their growing irrigation demand. A clear preference for privately owned water assets such as in wells and/(or) borewells over shared ownership of wells (common wells) is observed (Table E2.3). Investment in water assets increased with increase in the size of land holding.

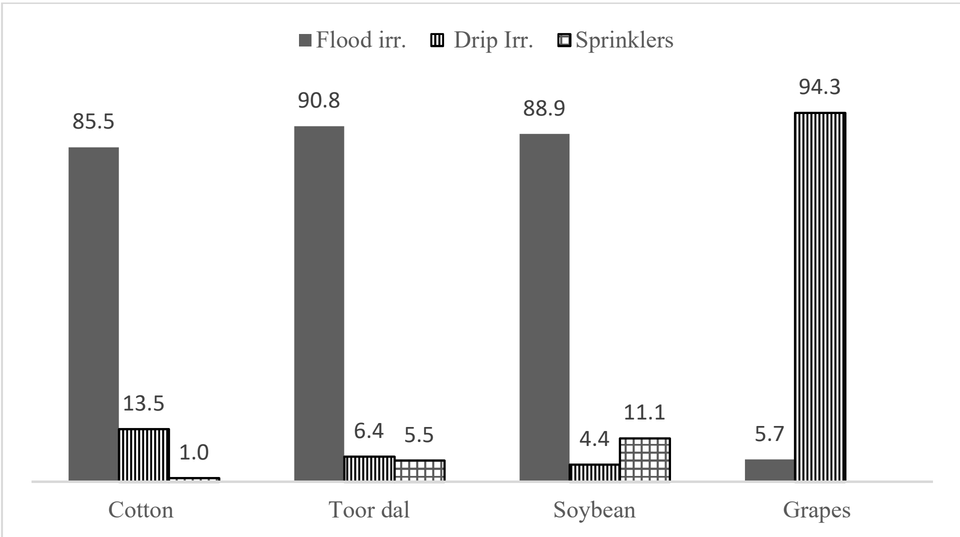
Table E2.3: Ownership of wells across land holdings in Villages 1 and 2

Land holding	Land holding size (acres)	n	Wells	Bore wells	Farm ponds	Common wells
			Village 1			
Marginal Farmers	< 2.5	82	72	0	14	4
Small Farmers	2.5 to <5	106	98	0	41	2
Semi-medium Farmers	5 to <10	111	141	0	86	1
Medium Farmers	> 10	33	65	0	38	0
Total		332	376	0	179	7
			Village 2			
Marginal Farmers	< 2.5	28	10	4	0	3
Small Farmers	2.5 to <5	30	16	9	0	4
Semi-medium Farmers	5 to <10	47	34	16	5	4
Medium Farmers	> 10	23	19	11	3	1
Total		128	79	40	8	12

Data source: Primary data

In addition to investment in portfolio of irrigation assets, farmers also invested in irrigation systems. Agricultural extension agencies promoted various tools to improve water use efficiency particularly for cultivating horticulture crops with higher irrigation requirement. Setting up drip irrigation systems for cultivation of horticulture is recognized as the necessary infrastructure accompanying horticulture farming (Figure E2.3). In Village 1, in addition to emphasizing the importance of cultivating horticultural crops under drip irrigated conditions, agricultural extension agency also laid emphasis on the need to adopt of rain water harvesting measures at the farm level.

Figure E2.3: Adoption of Water Use Efficiency Tools for Cultivating Commercial Crops (%) -Village 1



Data source: Primary data

Notably, adoption of water use efficiency measures is skewed towards high value crop production. Irrigation tools that are less investment intensive such as the sprinklers, were also not popular among farming households in both these communities. A plausible explanation to this irrigation tool adoption behaviour is the perception of crop vulnerability to insufficiency in irrigation availability. Horticulture crops are plantation crops, with an average productive life of 9 to 12 years. Adoption of drip irrigation systems facilitates suppling water for irrigation from a water storage structure (either from the wells or farm ponds) even under the conditions of dry wells in the village during summers. Water is imported into the village in water tankers and refilled into water storage structures supplying to drip irrigation systems. Non-adoption of water use efficiency tools for cotton, soybean and toor dal are because these crops are traditionally cultivated under rainfed conditions. Thirdly, the returns on investment for these rains fed crops are lower than land under grapevine cultivation.

E2.3.3 Evolution of Collective Action

Management of irrigation demand is critical to water resource and livelihood sustainability. WDP was implemented around the same time in both the villages. Capacity building efforts in setting up local institutions for resource management and endowing them with funds for maintenance was co-ordinated by the project implementation agency. After nearly two decades from programme implementation, evidence of collective action post-WDP was identifiable in the case of Village 1, but not in Village 2. Rules such as ban of borewells and encouraging farm level rain water harvesting were effectively implemented in Village 1.

Though factors such as locational advantage (agro-climatic advantages), access to market, and socio-economic characteristics of the villages may have contributed to success of Village 1; nevertheless, this study focus on the role of agricultural extension agency in building (enhancing/ channelling) social capital in the community to culminate into effective community based natural resource management.

(a) Collective Action in Village 1

WDP was completed in the year 2002-03. Prior to WDP, cotton cultivation was the primary income generating crop. Cultivation in kharif was shared between land allocated for cotton and subsistence cultivation. Post WDP implementation, land under commercial cultivation increased and horticulture was introduced and encouraged as the primary strategy to enhance agricultural livelihoods by the project implementation agency.

The early adopters of horticulture were a few landed farmers in the community. The average land holding size of those farmers were approximately 22 acres (Table E2.4). After 2003, when the WSD project was completed, until 2010, only about 30 farming households adopted horticulture. However, over the years the number of horticulture crop adopters picked up and as of 2017, nearly 60% of the farming households in the community were grape growers. The average size of total land holding evolved to be a weaker constraint over the years; as 90% of medium farmers, 75% of semi-medium farmers, 62% of small farmers and 35% of the total marginal farmers were horticulture adopters. Keeping up with the increasing pace of horticulture adopters, farm pond adoption picked-up since 2012.

Table E2.4. Timeline of Horticultural Crop Adoption

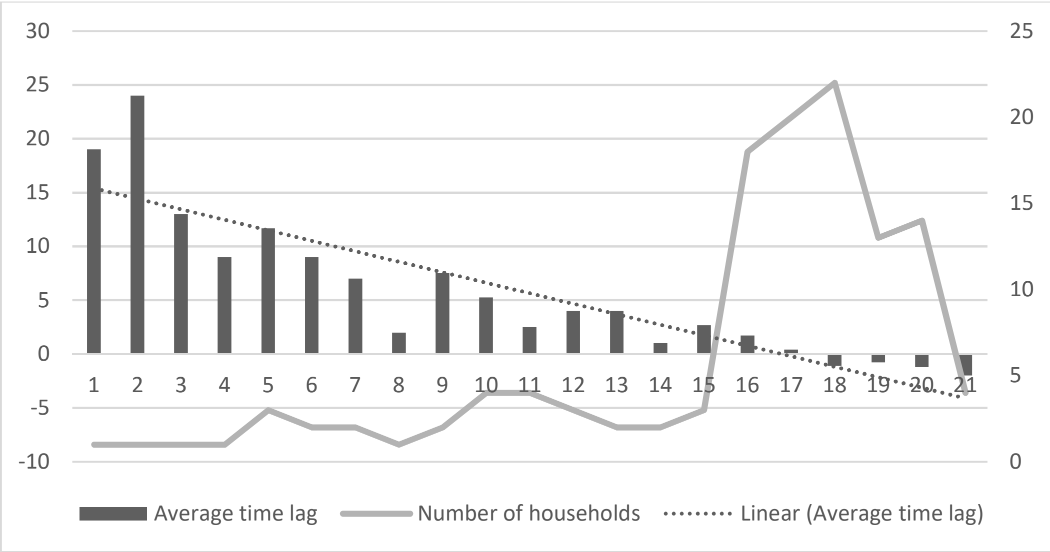
Year of adoption	Number of adopters	Average landholding size in each group (Acres)
Before 2000	4	22.25
2000-2005	16	10.26
2006-2010	13	9.00
2011-2015	109	6.83
2016-2017	45	4.07

Data source: Primary data

Demonstration of successful horticulture adoption implied a very challenging balance had to be struck between new and evolving irrigation demand and water harvesting capacity of the micro-watershed. The alternatives available then to increase irrigation supply were of well deepening and/or investing in borewell. The agricultural extension agency actively dissuaded the horticulture farmers from investing in borewells foreseeing it as a necessary precaution to preserve better groundwater health. Borewells drilled into the deep aquifers rendering the water table more porous. Punctures in the deep aquifers causes the overall water table to sink resulting in increasing the average depth of the wells in the village. Alternatively, farm ponds were introduced in the community by the agriculture extension agency as a measure of relieving dependence on groundwater.

Winning the trust of the villagers in the new technique required higher commitment in time and effort from the agriculture extension agency. The agency with prudent foresightedness worked out a strategy that encouraged widespread adoption of farm ponds. The leaders of the village local government, the members of the Village Watershed Development Committee (VWDC) and farmers who were well regarded (connected) in the community were the first ones to be convinced for adoption of farm ponds as an effective method to increase irrigation availability. The first farm pond in the village was constructed in the year 2001.

Figure E2.4: Time lag in farm pond adoption by farming households in Village 1



Data source: Primary data

Over the years, the time gap between decision to invest in farm pond and drip irrigation system as necessary infrastructure complementing horticulture declined (Figure E2.4). At present, a negative correlation between time of adopting farm pond and horticulture is observed, with infrastructure investments preceding crop planting. The declining time gap in adoption is plausibly because the farming community has accepted these infrastructure as necessary inputs. Also, because the community is capable of facilitating adoption of these infrastructure.

(b) Collective Action in Village 2

WSD programme was completed in the year 2002. Dovetailing, horticulture along with livestock was the recommended strategy to improve agriculture-based livelihood for dryland condition where average annual rainfall is less than 500 mm. The importance of cultivating horticultural plants only under drip irrigated conditions was also emphasized by the project implementing agency to enable the community to match the new irrigation demand with the water harvesting capacity of the micro-watershed. Like in Village 1, here too, it was the landed households who were the early horticulture and livestock adopters.

Changes in land under cultivation and crop choices of the households resulted in increased irrigation demand in the community as expected, however, the mismatch between water harvesting capacity of the micro-watershed and the irrigation demand of households encouraged them to invest more in well deepening and (or) borewells (Please refer Table E2.3).

The VWDC formed during the implementation phase of WDP was entrusted with the responsibility of managing the watershed after the completion of the project. However, the ability of the committee to mobilize collective action efforts and modifying social norms necessary for successful implementation of watershed project, faded post programme implementation. For instance, during the project implementation phase, the VWDC was effective in enforcing ban on tree felling and open grazing to protect afforestation efforts. However, with the withdrawal of the project implementation agency this committee ceased to be effective. Even maintenance works such as de-siltation of percolation tanks was rarely undertaken.

The inability to mobilize collective action post WDP may not be due to lack of capacity or experience in local governance. Following decentralization policies in the country since 1992, the village Panchayats are responsible for local self-governance. The Panchayat organized meetings on a monthly basis and among many concerns of village development, irrigation is one of the important concerns discussed. Discussions regarding future development of irrigation potential, de-siltation of water storage structures, securing drinking water supply and decisions regarding water provisions in rain scanty years are all made in these meetings. In the years of scanty rainfall, discussion on this platform is crucial to water provisioning arrangements, including for drinking water. It was also observed that farmers who have higher irrigation demand are the ones who participated actively in panchayat meetings. Active participation is inferred from the number of panchayat meetings the households attend in year. However, most of the discussions are focussed on irrigation supply augmentation. Steps to monitor groundwater health in the watershed are yet to be achieved.

(c) Comparison of Villages 1 and 2

The two villages were covered under the same development programme and around the same time, but community level management of resources have been successful in one village but not in the other. The difference in potential for rain water harvesting is one of the crucial factors in this regard. The poor potential for adoption of farm level water harvesting or other alternative techniques in Village 2 creates over dependence on ground water. Further, the availability of water in the wells are dependent on average rainfall the watershed receives every year. Unpredictability and insufficient availability of groundwater persuade individual households to act only in short term self-interest. On the other hand, Village 1 was able to utilize the water harvesting potential of the micro-watershed effectively with the support and hand holding of the WDP implementing agency, post completion of the project. Following early adopters, a clear pathway to successful horticulture adoption was paved and networks established within the village helping many other farmers to catch up. Identifying suitable early adopters and enabling others to follow encouraged pro-active formulation of local norms of groundwater use in Village 1. Institutional arrangement and social network facilitated effective enforcement of resource norms, in the necessary background of higher income accruing from agriculture.

E2.3.4 Empirical Model

To identify factors that influence farming households' decision to invest in farm ponds; literature identifying factors that influence farming household's investment in farm level soil and water conservation measures and crop choice adoption, were surveyed. In the literature, socio-economic attributes of the household, natural assets and institutional support were some of the identified factors that influenced household's investment decisions. In addition to these explanatory variables, a measure of social capital was included in this study to account for the influence of local norms pertaining to resource on irrigation assets ownership of individual farmers (Bouma et al., 2008).

Household investment in farm pond is treated as the explained variable. This variable was scattered across time; therefore, to enable the data worthy of comparison across years, household investment data was converted into real terms of money adjusting for inflation. The explained variable includes non-zero values corresponding to household investment and zero values corresponding to non-adoption of farm ponds.

Among the multiple factors hypothesised to influence household decisions to invest in farm ponds, empirical analysis is relied upon to identify the influence of each of the considered explanatory variables. Tobit regression model (or Censored Regression Model) is the appropriate method of estimation as the explained variable include non-zero continuous data along with zero to represent absence of investments.

The data for the analysis was collected through household survey enumerated to all households in the micro-watershed. Nearly 200 household in a total of 322 in Village 1 and 10 household in Village 2 invested in farm ponds. As the number of farm pond investment are very small in Village 2, the empirical analysis was only applied to data from Village 1.

The functional form,

$$Farmpond_{invest.} = \beta_0 + \beta_1 Agri.land + \beta_2 Agri.\ income + \beta_3 Hhlabour + \beta_4 Credit + \beta_5 Extension + \beta_6 Socialcapital + \varepsilon \qquad \text{Eq1.}$$

where,

$Farmpond_{Invest.}$ = Cost of constructing the farm pond in INR
Agri.land = Total land under cultivation in acres
Agri.income = Gross total income earned in an agriculture year in Indian rupees in INR
Hhlabour = Number of members in the household contributing to agriculture labour
Credit = Credit borrowed from formal institutions for agricultural purposes only INR
Extension = Perception of the household head on the effectiveness of agro-advisory provided by an extension agency

A five-point scale was used with 1= least useful and 5 = extremely useful,
0 = when the service is not subscribed

Social capital = Betweenness centrality score derived from social network analysis

Agricultural land *(Agri.land)*: Ownership and the size of agricultural land holding should encourage adoption of farm ponds. Ownership encourages private investments in soil and water conservation techniques (Pender and Kerr, 1998; De Graff et al.,2008) and; households with larger land holdings find it easier to allocate part of their land to soil and water conservation purposes (Udmale et al., 2014). The average dimension of a farm pond in the village is 24ft*24ft*3m and, multi-cropping is the dominant cropping pattern in the region. Nearly 58% of the farming households in Village 1 are small holding farmers with less than 5 acres of land; thus, the size of the land holding is expected to positively influence farm pond adoption. There are no instances of tenancy farming in the village.

Agricultural income *(Agri.income)*: Higher agricultural income is likely to encourage adoption of farm ponds. Agriculture is the primary source of income and farmers recognize horticulture as a high-risk high-return strategy. Higher resource dependence encourages households to value sustainability of resources (Gibson, 2001). Investment in farm ponds and drip irrigation systems are recognized as the necessary infrastructure investment for horticulture adoption. These investments reduce dependence on groundwater irrigation and also promote using water resources more efficiently.

Household labour *(Hhlabour)*: An increase in the number of household labour engaging with agriculture is expected to encourage adoption of farm ponds. Horticulture is labour intensive in nature and in absence of household labour contribution, farm labour is hired. Horticulture labourers require higher skills resulting in them commanding higher wages too. Therefore, with particular relevance to small holding farmers, increase in household labour contribution may encourage horticulture adoption and thereby farm ponds too (Pender and Kerr, 1998).

Credit: Increased availability of credit should positively influence adoption of farm ponds. By credit, we refer to loans availed for agricultural purposes alone in the last three years. Availability of credit will enable farmers to investment in conservation measures (Pender and Kerr, 1998).

Interaction with extension services *(Extension)*: Increased interaction with agricultural extension agencies should encourage investment in farm ponds. Interaction with extension agencies influence crop choice (Deressa et al, 2009), and in this context adoption of horticulture implies investment in farm ponds too. Further, engagement with extension agencies links farmers with network of agencies instrumental in construction of farm ponds too (Roy and Thorat, 2008).

Social capital: Higher levels of social capital in the community should positively influence adoption of farm ponds. Social capital is one of the determinants of successful community based natural resource management (Bouma et al., 2008). One, social capital can be a platform for social and knowledge support. Two, higher levels of social capital ensure reciprocity among resource users, keeping the cost of monitoring resource user's actions low (Pretty, 2002). Three, effective enforcement of resource use norms encourages collective action (Gibson, 2005). As a consequence, investment decision of farmers is likely to be influenced by both farming household level factors, and also by social norms.

In the literature social capital has been represented as, money sent in by the members of a society in a trust game (Bouma et al, 2008), number of relatives of a household in the local area and farmer to farmer extension (Deressa et al, 2009) and betweenness scores derived through social network analysis (Bodin and Crona, 2008). This research, chooses to represent social capital in the community as the betweenness scores; similar to Bodin and Crona, 2008 because, association among people in the community in critical in building adaptive capacity to overcome climate vulnerability (Pelling and High,2005; Olsson, Folke and Berkes, 2004).

To capture social network in the community, all the household heads in the community were asked to name three of their friends in the village with whom they engage in discussions to make agricultural decision. Positioning the household as the *node* and the list of friends as the *edges* in the network, the association between households in the community was identified using social network analysis. Betweenness centrality in social network theory calculates the shortest distance between the number of social ties between a sub-group of friends with other sub-groups in the community. This relation between the numbers of ties among members of one sub-group with other sub-group captures the idea of bonding in the village (Bodin and Crona, 2008). Open access software Gephi 0.9.2 was used in calculating betweenness centrality.

E2.4 Results and Discussions

All the explanatory variables considered in the model are significant at various levels and confirm to their expected signs. Their descriptive statistics are given in Table E2.5. Household labour contribution, agricultural credit availed, interaction with extension agency and social capital in the community are highly significant; total agricultural land and agricultural income are significant at 5% and 10% respectively. Table E2.6 is used to provide the detailed analysis of interaction between the investment in Farmponds and the explanatory variables.

Table E2.5: Descriptive statistics of explanatory variables in Village 1

	Units	Mean	S.D.	Min.	Max.
Total agricultural land	acres	5.63	5.96	0.5	52
Agricultural income	₹	335,637.1	629,982.4	0	6,467,000
Household labour	person	3	1	0	6
Credit	₹	248,065.2	31,4445.3	0	2,000,000
Interaction with agricultural extension	scale	0.75	0.432	0	1*
Social capital- betweenness score	score	4.81	11.94	0	85
n= 322 households					

*Binary variable

Table E2.6: Parameter estimates of tobit model

Explanatory variables		Village 1	
		Co-eff	P = |z|
Total agricultural land	Acres	1286.432	0.035**
Agricultural income	₹	0.0080	0.100***
Household labour	Person	5771.298	0.009*
Credit	₹	0.0539	0.000*
Interaction with extension agency	1-5 scale	5728.01	0.003*
Betweenness	Score	669.82	0.002*
Number of observations		322	
Uncensored		153	
Right censored		169	

*Significance: * at 1%, ** at 5% and *** at 10%*

An acre increase in land holding size increases investment of the household in farm ponds by ₹1,286. Nearly 60% of the farming households in the community belong to the category of small holding farmers with an average land holding of less than 5 acres. Addition of land assets provide an opportunity for crop diversification and including horticulture crops in the crop choice is an opportunity farming household aspire for. Including horticultural crops not only improves the chances of the farmers to increase their agricultural income, but also associates with itself a sense achievement. Data suggest grape wine cultivation is taken-up in land as small as 0.5 acres in this community.

A ₹1000 increase in agricultural income encourages an additional investment of ₹8 towards conservation. The low magnitude of influence of this variable is explained by the relation that, farm pond investments are fixed investments whereby the increase or decrease in annual agricultural income does not alter the investment required for installation of farm ponds. Threshold income levels, such as, the average levels of income that could be earned as a result of horticulture adoption is more likely to capture this relation more meaningfully. Secondly, the magnitude of influence of this variable may further drop when crop productivity is very high.

Addition of one more member in the household who is able to contribute to agriculture labour increases investment in conservation efforts by ₹5771. Horticulture is labour intensive and also requires higher skills; thereby labour cost may be a constraint to crop adoption, particularly when both the land holding size and the share of household labour is small. Further, hiring agricultural labour necessitates timely supervision to ensure quality of work. Additionally, working conditions under the canopy of vines (as opposed to working in open farms under day long heat) are milder, so the households have a preference of working themselves wherever possible.

A ₹1000 increase in credit increases conservation investment by ₹54. Access to agricultural credit plays a very significant role in influencing conservation decision - statistical significance of 1%; but the magnitude of influence is comparatively small. The smaller magnitude is justified because, the data collected through the survey captured information on agriculture credit availed in the last three years, whereas investment in farm pond is spread over time in the village. The members in the community have good access to agricultural credit; the average credit availed is ₹248,065 and there are rare instances of households availing credit from informal channels of credit.

Increased interaction of the household with the agricultural extension agency results in an increase of ₹5,728 to conservation investment. Agriculture is the primary source of income in this village and despite horticulture not being a popular crop in the region, this particular village has been able to achieve commercial success with horticulture adoption. Horticultural farmers are more likely to work in close association with agricultural extension agency and these institutions are an important source of information for new variety of crops, crop diseases and weather. Additionally, they also conduct skill upgradation programmes for farmers. In the particular case of the study village, the extension agency is also a key source of business (market) information and links (networks) facilitating the produces from the village to fetch higher prices. In brief, the continued association with the extension agency post WDP has enable the community to bridge knowledge gaps required for successful and sustainable agriculture.

Social capital in the village encourages conservation investment by ₹670. The average betweenness scores of social ties in the community is 5.30 indicative of higher level of social capital in the community. A score of 5 implies that there are at least 5 short paths between a household and an influential farmer (the one who is the link between many other sub-groups of farmers within the village) in the community. Nearly 2/3rd of the farming households in the community are horticultural farmers and affected by similar concerns. Farmer networks with the community is an effective medium for knowledge exchange. Apart from discussions in person, farmers also make good use of electronic communication. Farmers chat groups on smartphones using a variety of apps where reported as an effective medium of communication between farmers in the community. These chat groups are further linked to other horticulture farmers outside of the community.

The overall water harvesting capacity of Village 1 is higher than that of Village 2. Therefore, a livelihood enhancement strategy planned on community choosing crops that are relatively more water consumptive and commercially successful at the same time; is more appropriate for Village 1. The need for adopting livestock was emphasized in the case of Village 2; however, it remained accessible only to a small percentage of farming households with both larger land holding and higher agricultural income.

Post WDP, increased irrigation potential allowed nearly all the land under kharif cultivation to be subject to commercial cultivation and horticulture across land holding sizes in the village. Higher income gains from commercial cultivation encouraged the farmers to value groundwater more dearly. The agricultural extension played a key role in leveraging farmers valuation of higher commercial gains to a resource use norm, safeguarding the health of groundwater resources.

The potential of the livelihood enhancement strategy to be imitated by a majority in the village is also decisive. In Village 1, successful adoption by a few landed farmers, and simultaneously developing a network in the village enabling adoption by many more farmers encouraged the community as a whole to value common pool resource of groundwater. During the fieldwork, in an interview with a farmer identified as influential farmers in the village by the agricultural extension agency said that, he earned supplementary income by undertaking construction works of farm ponds and installation of drip irrigation system in the village. An ecosystem supporting adoption of horticulture is likely to have enabled a larger share of small holding farmer to adopt horticulture farming.

In a long-term evaluation of the performance of micro-watershed, the timely setting of resource use norms, building social capital and establishing social network that facilitates households to abide by water use norms prevented farmers from over routinely depending on techniques of groundwater extraction from deep aquifers. For a question in the survey probing whether the farmers wished their children to take up farming as their primary source of income, nearly 67% responded with an affirmative.

In the case of Village 2, though the land under cultivation increased manifold times after WDP implementation; not more than 1/3rd of land under kharif cultivation was seen to be subjected to commercial cultivation. Food crop cultivation and thereby food sufficiency though are clear and tangible benefit accruing from WDP, however it is ineffective in triggering second order collective action. Commercial gains are a decisive factor. Consequently, resource users act in a manner to secure their own irrigation and give in to adopt practices such a deep borewells for extraction of groundwater. Resource users may only be partially aware of effects of their action on the resource system as a whole; particularly given the elusive nature of groundwater, and by the time the effects are evident, undoing the damage is costly in terms of time, efforts and resources.

Continuous engagement with project implementation agency may provide the necessary knowledge and potentially less damaging solution to evolving and increasing irrigation demands in the micro-watershed community. The project implementation agency continued to work with Village 1 post WDP, while in the case of Village 2, the agency retracted after project completion. Notably, implementation agency in Village 2 worked for nearly 8 year with the village community during the project implementation phase, yet when the contact was withdrawn, the collective in the community also faded.

E2.5 Conclusions

This study attempted to identify factors that influence household's investment in water conservation efforts. Conservation investment by individual farming households have both private and public benefits. Private benefits as a result of diversified sources of irrigation and public benefit from reduced individual dependence on common groundwater. Post WDP, the irrigation availability in the watershed communities increases, consequently crop choices and cropping patterns change. It is the income that accrues from agriculture that encourages farmers to invest in conservation efforts; an observation similar to Gibson (2005) in the case of households depending on forest produces.

Groundwater resource is a common resource, however as the access to this resource is privately held, farmers tend to act in self-interest (Joshi et al, 2004). The elusive nature of groundwater makes it difficult to gauge the impact of resource use, or, farmers are not fully aware of how their water extraction actives impact the health of the resource system as a whole. Therefore, institutions that have a knowledge advantage can play a key role in helping local resource governance institution to spread awareness regarding conservation in the community. The agency also helps identify appropriate resource use norms.

Setting up an ecosystem that enables the adoption of water conservation measures will encourage many more farmers in the community to invest in the same. The social network in the community enables setting up of such conducive circumstance. When a larger share of the community is able to take up horticulture farming and invest in conservation, safeguarding resource health become the need of the community.

In resource poor regions, as the agricultural income is small, resistance to collective action and resource use norms setting is stronger. The cost of collective action in terms of time and effort is high in comparison to what could be earned from agriculture. The local resource governance became less effective in influencing the community and eventually ceased to function. Horticulture farmers in the village, thus invested in various irrigation assets, including the farm ponds; however, farm ponds are water storage structure rather than water harvesting structures in the village.

Essay 3

Water Resource Stacking: Resilience Building for Sustainable Livelihoods in the Semi-arid regions of India

Abstract

Farmers change their crop choices to include high value commercial crops, and/ or shift their farming pattern to bring more land under commercial cultivation after the implementation of WDP. Consequently, irrigation demand from the watershed system increases and farmers strive to secure their increased irrigation demand by individually and privately investing in multiple irrigation access sources, a phenomenon referred to as Water Stack in this study. The essay argues that, the constituents of a household's water stack is influenced by the state of resource use norm enforcement in the community. Three watershed communities from the semi-arid regions of Maharashtra have been studied here. In communities with poor norm enforcement, individuals invest in water stacks that may improve their irrigation sufficiency, but at the cost of resilience of the micro-watershed system. Multi-nominal probabilistic regression has been used in this study to perform empirical analysis. Formulation and enforcement of norms are more likely to occur when potential loss of livelihood are high as a result of non-cooperation among resources.

Keywords: Micro-watershed, water stack, watershed system resilience, collective action, norms

E 3. Introduction

This study attempts to contribute to the literature of sustainable management of micro-watersheds by analysing factors that influence household's choice of water stack under heterogenous natural settings. Potential loss in income gains from agriculture, can become a key driving factor for generating collective action in the micro-watershed communities.

Rainfed agriculture is practiced in nearly two-thirds of the cultivated land in India and increasing instances of climate variability have jeopardized stability and sustainability of agricultural livelihoods. Improving the prospects of cultivating land under irrigated conditions is critical to stabilise and improve these livelihoods. The current water resource management programme for dryland regions, the (Watershed Development Programme) WDP, attempts to enhance rural livelihoods by reducing complete dependence on seasonal rainfall for their productivity. The programme enables the harvesting of annual rainfall and retains it as groundwater resource available for use later.

Studies evaluating the benefits of such programmes have reported that land under cultivation, intensity of cropping and agriculture production have increased (Joshi et al, 2005; 2008). However, it has also been shown that the irrigation demand in the micro-watershed increases such that harvested water is sufficient only in years of very wet rainfall (Batchelor, 2004). This increased water demand could be due to the shift towards water intensive crops for livelihood enhancement as market for dryland products is absent and variety of high value dryland crops is limited (Bouma and Scott, 2006). Such shifts in crop choice have implications for sustainability of watersheds, particularly in the context of increasing vulnerability of dryland agriculture to climate variability.

Watersheds are common pool resources and their sustainability can be achieved only when groundwater resource users are able to coordinate their resource use actions. But, achieving coordination is difficult as benefits that accrue from WDP are diverse across its various groups of users (Kerr, 2007). Increased land under cultivation and thereby higher agricultural income are more likely benefits for farmers with significant land holding n the community, whereas increased land under food crop cultivation and secured drinking water are the likely outcomes for the small holding farmers. With such varied distribution of benefits from the programme, resource users may perceive the benefits of coordination actions very differently; especially in resource scarce conditions (Joshi et al., 2004). Additionally, unlike collective action required for implementation of the programme[19], which can be mobilised by participatory planning and transferring management of watersheds to the community, it is unclear how collective action required for maintenance (second order collective action) of watershed could be encouraged to safeguard resource sustainability (Agrawal, 1999). Nevertheless, literature on community based natural resource management and adaptive capacity building have highlighted the need for strengthening local institutions for resource management (Armitage, 2005; Wostl,2009).

The effectiveness of local resource governance institutions would be reflected in enforcement of resource use norms[20] which in turn influence households' resource use. This study focuses on the manner in which resource use norms in the community and households' need to build climate resilience, interact with each other to produce livelihood outcomes.

A concept referred to as '*water stack'* is introduced here to analyse the same. It can be considered in a manner to be similar to the established concept of energy stack. Energy stack model implies households invest in multiple energy carriers at a point in time to satisfy their energy requirements. These stacks may be influenced by tastes and preferences, availability to name a few (Kroon,2013). Similarly, households invest in multiple water access points such as wells, borewells or farm ponds to fulfil irrigation requirements and build climate resilience and it is this collection of irrigation access points that is referred to as water stack. Households in communities that value resource sustainability (resource use norms are enforced) will choose a water stack that is most likely to build both individual and community resilience concurrently. On the contrary, in communities where resource use norms are absent; household's choice of stack will be such that farming households' resilience is built at the expense of community resilience.

While norms play an important role in safeguarding resource health, enforcement of resource use norm in community is not usual. Inability to encourage second order collective action is a common place in the watershed development discourse (Reddy et al., 2004; Samuel, 2007). Therefore, to understand the relation between resilience building for sustainability of livelihood; this research focusses on the question, what are the household level factors that

[19] Prior to programme implementation, agricultural livelihoods in degraded natural conditions result in poor productivity and thereby modest agricultural incomes. Programme implementation provides an opportunity for everyone in the community, including the landless to improve their income. The landless gain wages through their labour services required for soil and water conservation treatments.

[20] The term norm is used with reference to rules enforced by the local governance institution. Since 1992, India follows a system of decentralized governance, delegating powers to local institutions. However, though the rules can be legally enforced, they are mostly observed as guidelines.

encourage farmers to choose a particular category of water stack. Concerned with increasing variability in climate variability, the study also attempts to link current choice of water stack, current livelihood outcome and the preferred choice of resource management to further build climate resilience and livelihood sustainability.

The rest of the paper is organized as follows: Section E3.1 provides details of the study region, Section E3.2 discusses the concepts of water stack and collective action and the method of analysis, Section E3.3 presents the results and Section E3.4 summarises the inferences drawn.

E3.1 Study Region

Three micro-watershed village communities located in the semi-arid districts of state of Maharashtra, India have been chosen for the study. WDP projects planned at the micro-watershed scale and implemented through participatory planning with the community was first implemented in this state. The chosen three villages belong to the first few micro-watersheds covered under the development programme. Nearly 15 years that have passed since the project completion, allows the study of communities with experience in groundwater management, and how they have been able to address, both, livelihood sustainability and resource sustainability.

The performance of a micro-watershed is dependent on the average annual rainfall a region receives. Two of the study villages are located in the district of Ahmednagar which receives an average annual rainfall of about 380 mm to 430 mm; and the third village is located in the district of Jalna which receives an average annual rainfall of 720 mm. The relatively sparse rainfall in Ahmednagar, almost half of that in Jalna, is likely to further challenge the management of micro-watershed, and therefore two villages located on either side of the ridge lines were studied, to account for better representation of the district. Among many other districts in the state, the Atlas of Vulnerability of Indian Agriculture (CRIDA, 2013) identifies these districts as highly vulnerable to climate variability.

E3.2 Water Stacking, Resilience and Collective Action

High variability and poor spatial distribution of rainfall makes semi-arid regions global hot spots of insufficient agricultural opportunities. Providing access to irrigation, and effective management of water resources can weaken one of the many constraints of dry land agriculture

(Rockstrom et al, 2010). WDP aims to provide this critical access to irrigation by enabling communities to tap the potential of groundwater tables. Implementation of WDP improves groundwater level within the watershed and consequently encourages farming households to invest in private ownership of well(s). It is observed that, over time, farming households invest in more than one water access point i.e. wells, borewells or farm ponds, to match their increasing irrigation requirements. Among these, wells and borewells are sources of groundwater; while farm ponds are sources of surface water (farm ponds are structures constructed to harvest annual seasonal rainfall at the farm level). This process of adding irrigation access points is referred to as *water assets* in this study. In other words, it refers to the total number (horizontal summation) of various irrigations access a household privately owns. Although, wells and borewells access the same groundwater, the very presence of these access points does act as an additional asset for the household.

The expansion in ownership of water assets may be an outcome of farming household's ability to increase land under cultivation. As can be seen in Table E3.1, the numbers of water assets owned by a farming household increased as the land holding size increased across all the three study villages. Alternatively, the expansion could be driven by the need to meet shortfall in existing irrigation demand as a result of increase in the overall demand for irrigation in the community (Singh, 2018; Batchelor et al., 2003). In case of Villages 2 and 3 where the annual average rainfall received is less than 500 mm, households owning greater than 5 acres had at least 2 water assets and were able to bring 30% of their land under irrigated commercial cultivation. Village 1, which receives an annual average rainfall greater than 700 mm, the same category of farmers owned 2 or 3 water assets and irrigated more than 90% of their land under commercial farming (Table E3.1).

Table E3.1: Distribution of water assets across various land holding sizes in the study villages

Land holding	N	Wells	Bore wells	Commo n wells	Farm ponds	Average Water Assets	Land under comme rcial farming
Village 1 Kadwanchi							
Marginal Farmers	82	72	0	4	14	1.09	84%
Small Farmers	106	98	0	2	41	1.33	85%
Semi-medium Farmers	111	141	0	1	86	2.05	93%
Medium Farmers	33	65	0	0	38	3.12	97%
Total	332	376	0	7	179	..	..

Village 2 Darewadi							
Marginal Farmers	28	10	4	3	0	0.61	20%
Small Farmers	30	16	9	4	0	0.97	22%
Semi-medium Farmers	47	34	16	4	5	1.25	30%
Medium Farmers	23	19	11	1	3	1.47	24%
Total	128	79	40	12	8	..	..
Village 3 Kumbharwadi							
Marginal Farmers	34	9	4	5	0	0.52	18%
Small Farmers	62	37	28	11	2	1.22	21%
Semi-medium Farmers	49	30	12	6	3	0.97	18%
Medium Farmers	23	25	9	3	1	1.60	29%
Total	168	101	53	25	6	..	..

Data Source: Primary data

Data in Table E3.1 also suggests that the nature of the water assets owned by farmers are different across the two rainfall zones. Wells and farm ponds constitute water assets in Village 1; whereas, wells and borewells constitute water assets in Villages 2 and 3. The nature (groundwater or surface water) of these water assets have different implications for resilience for households as individual entities or for the community as a whole. This choice of the water stack by farming households is referred to as *water stack* in this study. Improved resilience for individual households does not necessarily imply the same for the community as a whole. In an effort to manage household constraints - of land, financial assets and income generating potential of agriculture, farmers could choose to invest in a water stack that improves their resilience, but at the expense of community's resilience.

Particularly, for watershed communities located in regions receiving an average rainfall of less than 500mm, and given that the identified income enhancing strategy is adoption of horticulture crops; farmers are more likely to invest in borewells to fulfil their increased irrigation demand. Adoption of borewells punctures the water table and reduces the overall potential of ground water recharge within the watershed. Consequently, the productivity of wells in these regions decline, eventually further encouraging investment in borewells. This tendency is also catalysed by the lack of opportunity for farm pond adoption, as water harvesting at the farm level is feasible only in regions where annual average rainfall is more than 700 mm. Therefore, the ability of the community to act collectively and agree to resource use norms (second order collective action) is crucial for influencing individual action in the interest of resource sustainability.

Study villages 2 and 3 belong to dry land agriculture in regions receiving less than 500 mm of average annual rainfall, and adoption of horticulture and livestock was the identified strategy to enhance agriculture income. Following completion of WDP, the Village Watershed Development Committee (VWDC) was entrusted and also endowed with funds necessary for upkeep of the watershed. However, second order collective action was not mobilized in these villages. One of the plausible reasons is, farmers perceived the transaction cost involved in building collective action was high under relatively poor resource, and thereby, income generation circumstances. Less than 1/3rd of agricultural land was allocated to commercial cultivation after project implementation. The other 2/3rd was allocated to food crop cultivated under rain fed conditions. Relatively small income generating capacity of agriculture discourages farming households to invest time and effort to pursue second order collective action efforts in the community. This is primarily because, lower income does not allow substantial assets to be built, even over a longer duration. Consequently, there is neither the wherewithal, nor an incentive to undertake collective action once again, which in the first place did not provide any quantum increase in livelihoods.

Further, though higher participation and engagement with the local general governance body was pursued by horticulture farmers in the community, the group was unable to influence decisions in the interest of sustainability of resources. Less than one-third of households in the community have been able to adopt horticulture, and these too mostly belonged to the farmers who hold more than 5 acres of land. Thus, a very skewed nature of land holding is seen in the context.

Consequently, at present, most of the irrigation management imagination and discussions in the village, appears to be geared towards enhancing supply of groundwater, rather than being an effort to re-organize and coordinate farmers actions. In an interview with members of VWDC, they expressed the wish to construct cement boundaries around the percolation tank situated closest to the micro-watershed outlet from the village. In doing so, the water harvested within the village community will be retained in the village itself. Secondly, they also emphasised the need to re-cycle water already stored in the percolation tank such that an additional boost to ground water recharge could be provided. But none of the discussions were pertaining to monitoring of individual farmer use of resources.

In the case of Village 1 where the average annual rainfall is greater than 700mm, some evidence of second-order collective action is observed. Here too, the identified agriculture income enhancing strategy recommended was the adoption of horticulture. However, pre-empting an exponential increase in irrigation demand; the project implementation agency introduced farm ponds in the community shortly after project completion. A few landed farmers in the community with whom it had already built a close association during the phase of project implementation were chosen to work with. Landed farmers are more likely to have gained higher income from WDP, and adoption of farms ponds would further boost their income enhancement opportunity. After successful trials with farm ponds, the agency pursued the VWDC to promote and facilitate farm pond adoption.

The VWDC set resource use norms discouraging further dependence on groundwater, and also and concurrently established social networks to facilitate adoption. The knowledge support provided by the implementation agency helped the VWDC to raise awareness pertaining to the need for setting resource use norms, and also to identify effective ones. Ban of borewells was set as a rule before they started appearing in the community, to curtail tendencies that would encourage further dependence on groundwater to meet increased irrigation demand. Following this rule enforcement, a village social network was developed within the community to facilitate farm pond adoption. Few households in the community were involved with construction and repair of farm ponds; it contributed to their livelihood too. Thus, resource use norms set in anticipation of increased dependence on groundwater was backed with an alternative solution, encouraging surface water dependence. As a result, farm ponds and drip irrigation systems were identified as necessary infrastructure accompanying horticulture in Village 1.

In addition to an early introduction to resource use norms, commercial success in agriculture also plays an important role in their enforcement. Higher returns from agriculture allows farmers to assign higher value to perceived livelihood loss in the absence of effective irrigation management in the community. Currently nearly 60% of farmers in the community are horticulture farmers and its adoption spreads across all land holding sizes.

Early adoption of resource use norms, enforcement of norms and creating a social network encouraged bringing more land under horticulture cultivation in the community. However, increasing land under horticulture have resulted in irrigation insufficiency, particularly for those farmers during the summer. To close this irrigation gap, farmers import water into the village using services from water tankers. These tankers empty their water into the farm pond which is then used for drip irrigation. However, despite incurring both fixed cost (construction of farm pond) and variable cost (annual water tanker expenditure), horticulture is still the preferred crop choice in the community. Commercial gains from horticulture cultivation is large enough to prove decisive in encouraging both individuals and the community as a whole to safeguard groundwater resources.

E3.2.1 Interaction between Water Stack and Collective Action

Accumulation of water assets by farming households and the variety in the assets imply that farmers prefer to invest in a portfolio of water assets; referred in this study as - water stack. In Village 1, water stack consisted of well(s) and farm ponds, and in Villages 2 and 3 they invested in stacks consisting a combination of wells, borewells and farm ponds (Table E3.1). As an income maximizing agent, the farmer attempts to maximise returns from agriculture and minimise the costs associated with it; ensuring alongside that irrigation sufficiency is satisfied. In other words, a farmer is likely to choose a water stack that is a least cost opportunity, fulfils increased irrigation demand (or sustains current irrigation demand) and maximizes agricultural income. Since the income from agriculture in rainfed regions are vulnerable to other extraneous factors (i.e. Market price risks apart from climate risks) typically the lowest cost alternative is chosen by the household. Analysis of data on adoption of water efficiency tools for commercial crops suggested, even low invest tools such as sprinklers where not adopted by farmers in this village, while drip irrigation system was adopted for horticultural crops. Further, technical feasibility of alternative options and resource use norms in the community are other crucial factors that influence water stack decision.

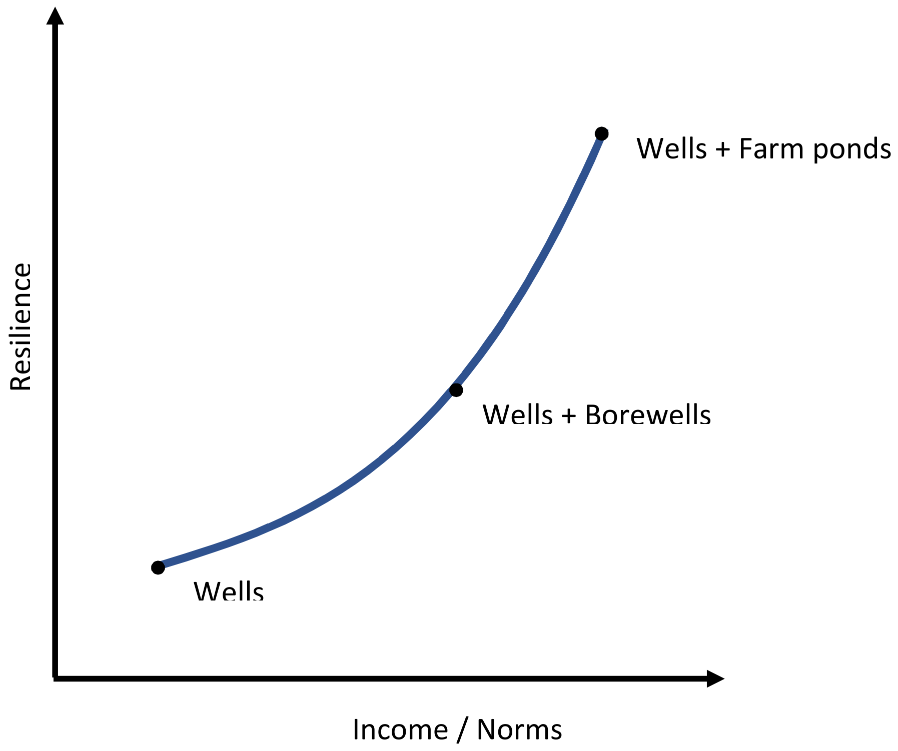
In other words, investments in water stack enable farming households to be more resilient against climate variability; the choice of a water stack supporting resource sustainability is more likely to be found in communities that enforce effective resource use norms; and norms are more likely to be effectively enforced in communities where income gains from agriculture is higher for a majority in the community. Thus, the average quality of a water stack of an individual farmer improves as income form agriculture increases, where quality is defined by the sustainability of groundwater resource system in the micro-watershed.

The literature on energy stacking explains that individuals move up the energy ladder model to less polluting choices as income increases. Further, the concept of energy stacking emphasises that the movement up the energy ladder is not a linear step-wise process, but households prefer to have a stack of energy sources. The nature of the stack may be influenced by the need to fulfil energy availability, taste and preferences, to name a few. However, the concept of energy ladder is used to analyse household behaviour and streamline policies and plans contributing to achieve objective of reducing air pollution; but, any similar analysis helping the cause of sustainable management of groundwater is missing. Management of groundwater within a micro-watershed is primarily focussed on one, improving institutional efficiency of local resource governance. Additionally, the need for fostering social aspects of community-based resource management is analysed; and role of leadership and participation of resource users (Kolavalli and Kerr, 2004) is discussed. To the best of the author's knowledge, literature recognising waters stacking behaviour of farmers and analysing factors that influence their choice of water stack is not available. Wells continue to be the identified as the main sources of irrigation and any alternative forms of groundwater extraction such as borewells, or surface water as farm ponds is addressed less frequently.

The choice of villages studied differ from each other in terms of average rainfall condition, nature of agriculture and experience of second order collective action. Village 1: receives an average annual rainfall greater than 700mm; rainfall harvesting at the farm level possible through construction of farm ponds; all land under commercial cultivation during kharif; resource use norms enforced. Village 2: receives an average annual rainfall less than 500 mm; farm ponds are technically not feasible; less than a third of land is allocated to commercial agriculture during kharif; and no resource use norms enforced. Village 3: receives an average annual rainfall less than 500 mm; farm ponds are not technically feasible, less than a third of land is allocated to commercial agriculture during kharif; no resource use norms have been enforced after WDP, however at present (during the field work in 2017) attempts to encourage second order collective action were observed. The community was in the process of negotiation with the project implementation agency, to get help in rejuvenating poor health of groundwater resources.

Wells proliferated in all the three villages after watershed development. In Village 1, where the income gains from agriculture was high, the perception of loss in agriculture income due to non-coordination among resources users was high enough to bring about collective action. Persuasion and support of project implementation agency enabled the community to value the need for setting and enforcing resource use norms. Thus, to supplement increasing irrigation demand, farmers invested in water stacks that increased household resilience but also supported good health of groundwater table (Figure E3.1).

Figure E3.1: Relation between Water Stacking and Resilience



In case of Villages 2 and 3, programme implementation increased the agricultural income of the households, but the gains were not high enough to encourage second order collective action. Transaction cost associated with collective action for long term income gains was higher than valuation of short-term gains from agriculture. Therefore, farmers built their resilience by investing in a water stack that improved household resilience, but at the cost of resource health.

The scope for stacking for irrigation is more limited than for energy because. the opportunities in case of irrigation in dryland regions are limited to two independent options: one, surface water supply as farm ponds or two, groundwater supply through wells or borewells. Adoption of farm ponds is viable only when commercial gains from agriculture is substantially high. Notably, in Village 1 where income gains are high, farmers import water into the village to meet irrigation requirements. In the agricultural year 2016-2017, nearly ₹ 6,000,000 worth of water was imported into villages through water tankers. Effectively, the water stack of farmers in Village 1 consisted of groundwater and surface water within the watershed, and the third opportunity of irrigation resource transfers from outside of the micro-watershed boundaries. This result reinforces the idea that as income increases the water stack of farmers improve in their quality defined in terms of supporting sustainable use of groundwater system, in the presence of collective action norms.

In case of Villages 2 and 3, where the average agricultural incomes are small, the options of irrigation are further limited to a choice of wells and borewells; a complete dependence on groundwater. Strong constraints in terms of both limited availability of irrigation resources and little gains from its use, excessive of responsibility is passed over to collective action. Collective action is difficult to achieve under relative resource scarce conditions, consequently, at lower level of income gains, water stacks achieve only short-term income gains.

Though second-order collective action for water resource management did not occur in the case of village 3, it provides an insight relevant to collective action. In Village 3, following WDP, farmers also invested in livestock to supplement their agriculture income. Many in the village were able to adopt livestock which eventually led to setting up of a milk cooperative within the village. Taking inspiration from milk cooperative and previous experience with failure of resource management, now encouraged farmers to pursue second order collective action for rejuvenating groundwater resources after nearly two decades since WSD project completion.

Water stack influenced by collective action (resource use norm) increases resilience of both individual farming household and the community as a whole. Therefore, facilitating and building up of collective action is of paramount importance. The case studies suggest that trigger for collective action is dependent of the characteristics of the watershed community. Village 1 located in a region receiving relatively high rainfall; implementation of WDP brought about significant income gains. Once the fundamental criterion of high-income gains was met, appropriate technology and an effective local governance brought about collective action resulting in a stack facilitating better resource health. Village 2 and 3 are located in region receiving relative low rainfall. Poor income gains from agriculture prevented collective action in both, yet Village 3 is more likely to achieve better groundwater conditions as there are some evidence of emerging collective action. Positive learning from milk cooperative success and poor experience with poor groundwater management following WDP influences the stage of current level of second order collective action.

E3.2.2 Empirical Analysis

Agriculture is the primary source of income in the study villages. Building resilience to climate variability enables farming households to secure agricultural livelihood and also achieve higher agricultural income. Increase in the size of the water stack and its constituents improve the resilience of farming households to climate variability. Sections until now discussed the role of collective action and resource use norms in shaping individual choice of water stacks. In this section, focus is placed on understanding the factors that influence household's choice of water assets in the presence and absence of resource use norms. Literature on farmers decision to invest in soil and water conservation efforts was referred to identify individual factors that are likely to influence household choice of a water stack.

Water stack is the dependent variable studied and is represented as a categorical variable. Households were assigned to category of water stack based on the constitution of their water stack. For instance, a farming household who owns only a well was assigned the value 1, households with a well and a borewell was assigned 2, and those with a well, borewell and farm pond was assigned 3. There are a few households who owned more than one particular water access point, yet the household have been assigned the category based on the variety in the sources of irrigation access and not the number of the same source. Emphasis has been given on the variety of sources as they are a better representative of the resilience in irrigation requirements for the household.

In general, studies analysing household's decision to invest in soil and water conservation examine the influence of socio-economic aspects of the household, natural assets the household owns and the involvement or support from institutional agencies it avails. Here, the variable considered includes ownership of natural capital, income gains from agriculture, household labour contribution and institutional support availed. These variables also associate to the five assets identified under the sustainable livelihoods' pentagon.

The dependent variable being a categorical variable, Multi-nominal Probabilistic regression is applied to for performing empirical analysis. Value 1 represents household investment in atleast 1 water access point and 3 represents investment in the most diverse water stack. Cross sectional nature data tend to suffer from violation of estimation conditions, particularly the issue of heteroscedastic. The estimated models were corrected for heteroscedasticity when detected.

The data for the analysis was collected through household survey enumerated to all the household in three micro-watersheds. Village 1 is home to nearly 370 households, Village 2 to 126 households and Village 3 to 176 households. Nearly all the household in the study villages are landed farmers, with a majority of them classified as a farmer with small land holding. The probabilistic regression analysis is run independently for the three villages as they are not directly comparable to each other. The villages differ in terms of the level of social norms, the choice of livelihood and the hydro-geological conditions (average annual rainfall received the nature of groundwater tables are different between Village 1 and Villages 2 and 3). Yet, they are comparable being in the semi-arid region and having experienced watershed development two decades ago.

The functional form,

$$Waterstack_{.} = \beta_0 + \beta_1 Comm.land + \beta_2 Agriincome + \beta_3 Hhlabour + \beta_4 Credit + \beta_5 Ext. + \varepsilon \quad \text{(Eq1)}$$

where,

Waterstack. = Category of water stack a household belong to

1 = when the household has invested in only one water access source (well)

2 = household has invested in two water access sources (well + borewell)

3 = household has invested in three water access sources (well + borewell + farm pond)

Comm.land = Total land under commercial cultivation during kharif (in acres)

Agri.income = Gross total income earned in an agriculture year (in INR)

Hhlabour = Number of members in the household contributing to agriculture labour (persons)

Credit = Credit borrowed from formal institutions for agricultural purposes only (in INR)

Extension = Perception of the household head about the effectiveness of agro-advisory provided by an extension agency (scale variable)

A five-point scale was used with 1= least useful and 5 = extremely useful,

0 = when the service is not subscribed

Commercial land (Comm.land): An increase in commercial land is more likely to encourage farmers to invest in an additional source of irrigation. The size of agriculture land holding and its type of ownership is one of the factors considered to positively influence household's decision to invest in soil and water conservation measures (Pender and Kerr, 1998, De Graff et al.,2008). In this functional form, the size of commercial land has been considered because data from the household survey suggested that farmers have a strong preference for cultivating commercial crops under irrigated condition. Food crops are primarily cultivated under rain fed conditions delinking it with the decision to invest in irrigation assets. In terms of ownership of land, land under tenancy farming is absent in all the three study villages.

Agriculture income (Agri.income): An increase in total agriculture income is likely to encourage farmers to invest in an additional source of irrigation (Mango et al., 2017). Adoption of high value crops is the recommended strategy to increase agricultural income in the dry land regions. A significant difference in average level of income was found between average income of horticulture adopters and non-adopters. Average income of horticulture farmers where nearly 9 times more than non-adopters in Village 1, 1.87 times more in Village 2 and 2.7 times more in Village 3. Adoption of horticulture crops also implies higher demand for irrigation to be met by the farming household, consequently raising investments in water stack.

Household labour (Hhlabour): An increase in the number of households contributing to agriculture is likely to increase investment in water stacks. Literature analysing factors that influence household decision to invest in conservation activities typically have not included household labour as variable, or have found the variable statistically insignificant, when it has been included. However, studies focusing on livelihoods of small holding farmers, report that contribution of household labour plays a significant role in increasing efficiency of horticulture farming among them (Joshi and Birthal, 2006). Horticulture farming is labour intensive and by employing household labour, farmers are able to achieve better productivity. A good majority of farming household in the study villages are small holder farmers with less than 5 acres of land under cultivation.

Credit (credit): An increase in credit availability is likely to increase investment in water stacks. Availability of credit provides an opportunity to invest in water assets (Pender and Kerr, 1998; De Graff et al.,2008). Data collected on credit availed and institutional source of credit suggest, farmers have access to credit and depend on formal institutions of borrowing. Notably, farmers' financial cooperative is a chief source of borrowing among small holding farmers.

Interaction with extension services (Extension): Increase in interaction with extension services is likely to increase investments in water stacks. Extension agencies provide advisory services and also farmer-to-farmer links that influence conservation investment decisions (De Graff et al., 2008). Secondly, increased contact with extension agency also influences crop choice decision of farmers (Ref.). The relation between extensions and crop choice could be a two-way causal relation, however for the current context, households' adoption of crop increases their investment in water assets.

E3.3 Results and Discussions

The model specification is highly statistically significant (probability < 0.00) for all the three villages. The results suggest, as agricultural income increases, investments in water stacks also increased across all the three villages. The reverse causality- investment in water stack causes an increase in income - could be true; however, as the concern here is with the process of accumulation of water assets, irrespective of the direction of causality, the relation an increase in agricultural income causes increase in investment in water stacks is more appropriate to the context of rainfed agriculture-based livelihood.

Apart from household income, in Village 1 where the annual average rainfall is greater than 700 mm, the size of the commercial land under cultivation and contribution of household labour influenced investments in water stacks. In the case of Villages 2 and 3 which received an annual rainfall less than 500 mm, the institutional factors of credit availability and interaction with the agriculture extension agency influenced the dependent variable. All the variables that are significant, confirm to their expected signs across villages.

Table E3.2: Descriptive statistics of explanatory variables

	Units	Mean	S.D.	Min.	Max.
Village 1					
Commercial land	acres	4.82	4.84	0	40
Agricultural income	%	355212.2	647611.5	0	6467000
Household labour	person	2.94	1.29	0	6
Credit	₹	258545.2	321715.1	0	2000000
Interaction with agricultural extension	scale	2.94	1.29	0	6
Village 2					
	Units	Mean	S.D.	Min.	Max.
Commercial land	Acres	1.28	1.49	0	10
Agricultural income	%	71169.05	117835.6	0	650000
Household labour	person	2.5	1.33	0	6
Credit	₹	80071.43	145198.1	0	670000
Interaction with agricultural extension	Scale	0.93	1.42	0	4
Village 3					
	Units	Mean	S.D.	Min.	Max.
Commercial land	Acres	1.04	1.64	0	12
Agricultural income	%	43817.77	92261.02	0	600000
Household labour	person	2.58	1.21	0	7
Credit	₹	62981.71	121960.8	0	600000
Interaction with agricultural extension	Scale	0.90	1.48	0	4

Data source: Primary data

Table E3.3: Multi-nominal probit estimates – Water stacking model

Village 1				
Explanatory variables	**Category 2**		**Category 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Commercial land	0.008	0.891	0.124	0.053**
Agricultural income	2.77e-06	0.000*	3.47e-06	0.000*
Hhlabour	0.283	0.004*	0.408	0.001*
Credit	1.01e-07	0.082***	1.12e-07	0.093***
Extension	0.050	0.483	0.060	0.581
Constant	-2.071	0.000	-4.445	0.000
Base outcome	Category 1		Category 1	
Wald Chi2	61.94			
Prob > chi2	0.000			

Village 2				
Explanatory variables	**Category 2**		**Category 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Commercial land	-0.010	0.946	-0.368	0.156
Agricultural income	3.33e-06	0.113	9.66e-06	0.000*
Hhlabour	0.104	0.462	-0.248	0.144
Credit	1.46e-06	0.300	3.52e-06	0.011**
Extension	-0.073	0.568	0.064	0.769
Constant	-1.133	0.006	-1.952	0.001
Base outcome	Category 1		Category 1	
Wald Chi2	56.17			
Prob > chi2	0.000			

Village 3				
Explanatory variables	**Category 2**		**Category 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Commercial land	0.082	0.428	0.051	0.637
Agricultural income	3.12e-06	0.024**	2.75e-06	0.100***
Hhlabour	0.075	0.553	0.236	0.216
Credit	2.04e-06	0.103	4.18e-06	0.006*
Extension	0.037	0.727	0.246	0.085**
Constant	-1.524	0.000	-3.589	0.000
Base outcome	Category 1		Category 1	
Wald Chi2	59.95			
Prob > chi2	0.000			

*Significance: * at 1%, ** at 5% and *** at 10%*

Table E3.4: Marginal Effects

Village 1				
	Category2		**Category 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Commercial land	-0.006	0.647	0.016	0.037**
Agricultural income	5.75e-07	0.0003*	2.80e-07	0.000*
Household labour	0.054	0.036**	0.036	0.010*
Credit	2.19e-07	0.134	8.16e-09	0.260
Extension	0.010	0.599	0.010	0.332

Village 2				
	Category 2		**Category 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Commercial land	0.014	0.707	-0.017	0.333
Agricultural income	1.37e-06	0.013*	5.77e-07	0.055**
Household labour	0.036	0.295	-0.014	0.156
Credit	2.97e-07	0.366	1.59e-07	0.064**
Extension	-0.007	0.808	0.007	0.535

Village 3				
	Category 2		**Category 3**	
	Co-eff	P = |z|	Co-eff	P = |z|
Commercial land	0.020	0.394	0.001	0.761
Agricultural income	8.79e-07	0.012*	1.28e-07	0.095***
Household labour	0.014	0.629	0.011	0.301
Credit	4.63e-07	0.114	1.94e-07	0.063***
Extension	0.007	0.728	0.012	0.069***

*Significance: * at 1%, ** at 5% and *** at 10%*

Based on the results (Tables E3.3 and E3.4) the following variables have been interpreted to describe their effect on water stacking decision.

Commercial land holding: An increase in the size of commercial land holding was expected to increase investments in water stack, and this relation is significant in case of Village 1. An addition of an acre of land under commercial land increases the probability of investing in an additional water access point by 11%. Village 1 has a natural advantage of being located in a region which receives relatively higher rainfall, facilitating recharging of groundwater and resulting in better well productivity.

This relation was statistically insignificant in the case of villages 2 and 3. In these villages, less than a third of the total cultivated land was subjected to commercial cultivation.

Further, crop diversification is also a dominant strategy used by the farmers to build climate resilience. To increase agricultural income, farmers may choose a crop portfolio with a combination of high value irrigation demanding commercial crops and less irrigation demanding dry land commercial crops. In short, an increase in commercial land need not imply increase in land under irrigation demanding commercial crop, and therefore a weak relation between land under commercial cultivation and investment in water stacks.

Agricultural income: An increase in agricultural income is expected to increase investment in water stacks and this expected relation is statistically significant in case of all three villages. However, less than one 1% probability is estimated in the case of all three villages. Low probability estimates could be because, the income data recorded is for the current year, whereas investment in water stacks are decisions implying expenditure across many years, thereby weakening the results measuring the degree of influence.

Household labour: An increase in the labour contribution by a household is expected to increase investment in water stack and this expected relation is statistically significant in case of Village 1. Nearly 90% of the total land cultivated during kharif is allocated to commercial cultivation. Further, nearly 65% of the farmers across all land holding sizes, allocated a share of their land to horticulture. Widespread commercial nature of agriculture encourages farming households not to diversify into alternative livelihoods opportunities and contribute their labour to agriculture. Further, horticulture is a high skilled labour-intensive occupation. Households, particularly small holding farmers, have a preference to work on their own farm as compared to hiring farm labour. However, the estimates of increase in probability of investing in water stack as a result of increase in household labour supply is less than 1%. A representation of household labour contribution in terms of labour hours/days may have improved the result. In case of Villages 2 and 3, a larger share of land is under food crop cultivation and households resort to income diversification strategies to secure their livelihoods.

Credit: An increase in credit is expected to increase household's investment in water stack and this expected relation is statistically significant in case of Villages 2and 3, a very weak significance in case of Village 1. Average agricultural income in these villages are relatively low in comparison to national average income of agricultural households of approximately ₹72,000 per annum. The average income in Village 1 is ₹71,000 and in Village

2 is ₹ 43,000 approximately. Lower agricultural income provides less opportunity to plough back household income for investment in necessary agriculture infrastructure.

Here too, the probability estimates of increase in credit to increase in water stack investments are low for the same reason as the unit effect of agricultural income on water stacks. The data on credit used is reflective of credit availed for agricultural purposes in the recent years (loans taken since 2014). While investment in water stacks are spread over year. Also, agricultural loans are availed for multiple reasons, investment is water stacks are one of those many. Average level of income in the Village 1 is nearly 5 times more than that of Village 2 and 8 times of Village 3 (Table E3.2). Higher agricultural income reduces household dependence on credit for assets creation.

Extension: An increase in access to agricultural extension agency is expected to increase household's investment in water stack and this expected relation is statistically significant in case of Village 3. Notably, this variable is significant only in the case of households who belong to the category 3 – ownership of at least three sources of irrigation access. Thus, the chance of these households including a horticultural crop in their portfolio is very high; particularly so, because livestock is widespread in this community. To successfully manage horticulture in resource scarce conditions, farmers depend on agricultural advisory.

Among land, income, labour, credit availability and access to agricultural extension as the explanatory factors; income is the prime factor that drives household's investment in water stacks. Increase in income encouraged farming households to add to their water stack. In regions receiving higher rainfall, increased investment in water stack also implied increase in land under cultivation. But, in the case of regions with poor rainfall, increased investments are primarily to ensure or secure irrigation sufficiency for the existing land under commercial cultivation. Notably, despite investment in water stacks, as the productivity of the stack is still dependent on the average annual rainfall the region receives, water imports were common in all three study villages.

Apart from income, credit availability of the households influenced farming household's decision to invest in water stacks. Small sized loans availed from farmers' cooperatives is characteristic of the financial liabilities of most households in Villages 2 and 3. Loans could be availed from farmers' cooperative at lower interest rates and also had the provision of rolling over annually. Farmers in the resource rich region availed agricultural loan from national banks.

E3.3.1 Water Stacking and Preference for Collective Action for Resource Maintenance

The concept of water stack as constructed in the study does not clearly account for the relation between choice of stack and its impact on groundwater health. An increase in the stack is not necessarily indicative of higher extraction of groundwater. For instance, in Village 1, where resource use norms are enforced as a result of collective action, the choice of water assets diversified between groundwater (wells) and surface water irrigation (farm pond). In Villages 2 and 3, where resource use norms are absent, a water stack consists of wells (groundwater), borewells (deep extraction of groundwater) and very few instances of farm ponds (surface water). Thus, water stack in Village 1 is more resilient as irrigation demand is shared between groundwater and surface water, relieving over dependence on groundwater as a consequence of evolving agricultural aspiration. It is the emergence of second order collective action that enables enforcement of resource use norms influencing household's decision on water stack in favour of resource health.

Under the premises that, resilience building is key to sustainable livelihoods in resource scarce regions, and given that the studied communities have nearly two decades of experience in local resource management; it is beneficial to understand what their preferred manner of resource monitoring is. Such concerns arise particularly from clear signs of insufficiency in irrigation availability across all the three villages (water for irrigation is imported in all the three villages) and increasing climate variability. In other words, the current household water stack and livelihood sustainability achieved is an outcome of the previous levels of collective action in the community; the goal is to identify effective incentives/strategies for resource management to ensure sustainable livelihoods by increasing resilience both at the household level and the community as a whole.

The hypothesis is, collective action preference of a household for resource monitoring is influenced by natural capital endowment with the farmers, the livelihood gains that accrues to the household, aspiration in terms of possibility of increasing agricultural income and belief in a form of cooperative in order to achieve better livelihood. Natural capital is represented by land size; livelihood gains by income from agriculture and allied activities; agricultural aspiration in terms of choice of crops in future – a choice between food crop for self-consumption or cash crop; and belief in formal cooperative association – membership in any form of farmer's cooperative. All the four explanatory variables are expected to positively influence household's preference for monitoring resources as a collective. Multi-nominal probabilistic model is applied to the data for inferences.

$$CollectiveAction = \beta_0 + \beta_1 Land + \beta_2 Agriincome + \beta_3 Futurecrop + \beta_4 Cooperative + \varepsilon \quad \text{(Eq2)}$$

CollectiveAction = Collective action preference a household belong to

1 = household prefers individual/private management of resources

2 = household prefers collective management of resources

3 = when the household prefers a third-party management of resources

Land = Total land under commercial cultivation (in acres)

Agri.income = Gross total income earned in an agriculture year (in INR)

Futurecrop = Prefers to add more food crops (0) or commercial crops (1)

Cooperative = Prefers membership in cooperative society, no (0) and yes (1)

Figure E3.2: Innerconnectedness of the groundwater

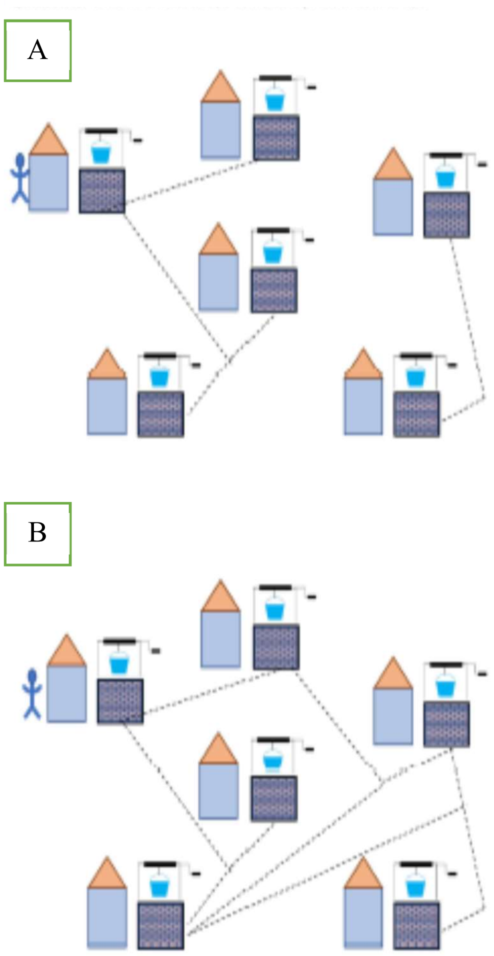
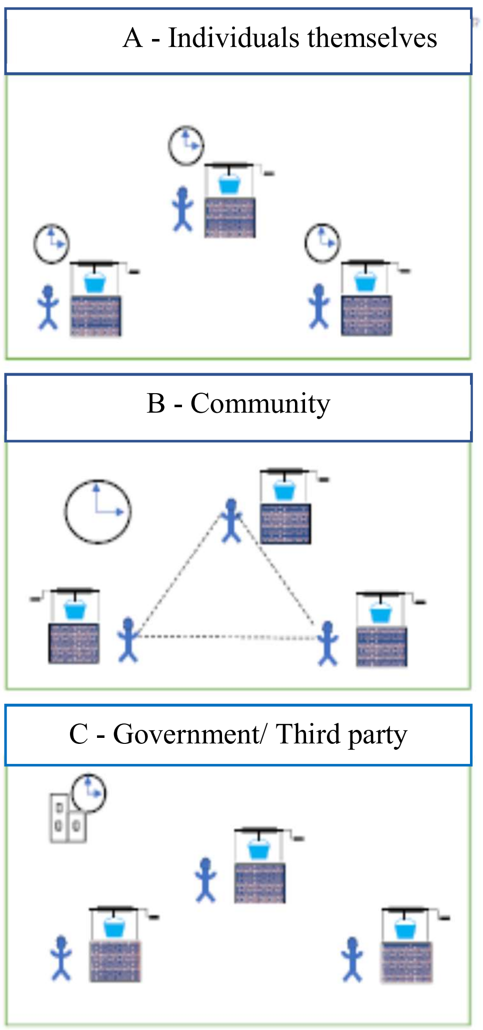


Figure E3.3: Collective action prefernce for resource monitoring



Figures E3.2 and E3.3 are illustration used in the household survey to collect data on collective action preference of the household. The awareness pertaining to the interconnected nature of the resource was first collected, followed with a question on preference for collective action. The average awareness pertaining to interconnectedness of wells (i.e. groundwater is a common pool resource) is high as a result of awareness generated on watershed resource system during the initial phase of project implementation.

Land: Increase in land holding is likely to influence household's preference for monitoring of resources as oppose to self-monitoring. Demand for irrigation increases with more land under cultivation implying the need to secure irrigation also increases.

Income from agriculture and allied activities: Increase in agricultural income is likely to influence household's preference for monitoring of resources. The opportunity to earn higher income depends on irrigation availability and thereby the need to secure irrigation also increases.

Future crop: Increase in preference for cultivating commercial crops is likely to influence household's preference for collective action. Commercial crops are cultivated under irrigated conditions, and a preference to grow commercial crop is indicative of household interest in securing groundwater health for dependable source of irrigation.

Cooperative preference: Increase in preference for membership in a cooperative is likely to increase preference for collective action. Farmers choosing to associate themselves with institutionalized cooperatives could be indicative of their belief that benefits may potentially arise from this association with a collective.

Table E3.5: Collective action preference for resource monitoring across villages

Collective Action Preference	Village 1(KD)	Village 2(DW)	Village 3(KU)
Self-monitoring	70%	24%	16%
Collective monitoring	14%	64%	71%
Third party monitoring	16%	11%	12%

Table E3.6: Multi-nominal probit estimates – Collective action preference model

Village 1				
Explanatory variables	**Collective management**		**Third party management**	
	Co-eff	P = |z|	Co-eff	P = |z|
Land	-0.042	0.272	-0.054	0.106
Agricultural income	-5.53e-07	0.223	-2.18e-08	0.945
Future crop	1.023	0.001*	1.000	0.002*
Cooperative preference	0.369	0.009*	-0.360	0.030**
Constant	-2.214	0.000	-1.250	0.001
Base outcome	Self-monitoring		Self-monitoring	
Wald Chi2	37.20			
Prob > chi2	0.000			

Village 2				
Explanatory variables	**Collective management**		**Third party management**	
	Co-eff	P = |z|	Co-eff	P = |z|
Land	-0.028	0.571	-0.043	0.461
Agricultural income	-2.504e-06	0.040**	-1.35e-06	0.391
Future crop	-0.720	0.142	-0.113	0.837
Cooperative preference	1.801	0.000*	0.318	0.503
Constant	0.862	0.067	-0.096	0.865
Base outcome	Self-monitoring		Self-monitoring	
Wald Chi2	38.76			
Prob > chi2	0.000			

Village 3				
Explanatory variables	**Collective management**		**Third party management**	
	Co-eff	P = |z|	Co-eff	P = |z|
Land	-0.039	0.378	-0.122	0.086***
Agricultural income	4.75e-06	0.063**	6.43e-06	0.021**
Future crop	0.104	0.768	0.994	0.039**
Cooperative preference	0.814	0.030**	-0.172	0.704
Constant	0.458	0.242	-0.649	0.212
Base outcome	Self-monitoring		Self-monitoring	
Wald Chi2	18.21			
Prob > chi2	0.019			

*Significance: * at 1%, ** at 5% and *** at 10%*

The model specification is highly statistically significant (probability <0.00 for Villages 1 and 2 and probability <0.01 for Village 3). The probit estimates of the model are present in Table E3.6, however the marginal effects caused by each of the explanatory variables are not included. The dependent variable is an aspirational variable and so are two of the explained variables. For a lack of unit of measure that could be associated to perceptions, the marginal effects results are not interpreted.

In Village 1, only 16% of farmers (Table E3.5) chose collective management of resources as the preferred means of resource management. Among the explanatory variables considered in the model, aspiration to grow cash crops and belief that a cooperative membership is beneficial drives this preference. The preference for growing more cash crops and association with formal cooperative institutions is indicative of farmers aspiration in engaging with the market to earn higher agricultural income. In an interview with the Senior Agriculture Extension officer said, “farmers in the villages were actively engaging in negotiations with Maharashtra Grape Growers Association to be able to export grapes to Russia”. Experimenting with new varieties of grapes, monitoring of grape productivity, all indicates market readiness in this farming community. Notably, horticulture farmers also incur high cost in importing water for meeting irrigation requirements of horticulture crops. The higher cost of cultivating encourages them to identify pathways to earn higher income too.

This result is indicative that once the second order conditions have been effectively enforced, farmers may depend on more formal institutionalized collectives or the market itself to ensure livelihood sustainability.

In case of Villages 2 and 3, 64% and 71% of the farmers (Table E3.5) choose collective management of resources. This category of farmers also earned higher income from agriculture in comparison to farmers who chose self-monitoring of resources. Further, they also preferred to be members of farmers’ cooperative association. Poor agricultural productivity, limited irrigation capacity and failure of achieving second order collective action in the past, possibly encourages people to identify coordination of resource use behaviour as a means to gain higher income. Particularly in case of Village 3, though second order collective action for maintenance of water resource did not emerge, a milk cooperative is well functioning in the village. Following WDP farmers invested in milch cows, and income from livestock has contributed towards a good share of livelihoods for many in this village community.

To summarise, successful second order collective action for resource management may evolve to depend on markets for building resilience. In the absence of second order collective action, communities may prefer to re-attempt collective action or may exit agriculture. Possibility of re-attempting to build collective action may emerge because of positive gains from previous collective action experiences.

E3.4 Conclusions

This essay studies the relation between household's livelihood sustainability and resilience building. Access to irrigation is the primary means to enhance livelihood sustainability among households in watershed communities located in the semi-arid regions. To bring in more land under irrigated cultivation or to sustain the current share of land under irrigated cultivation, households invest in multiple sources of irrigation. This collection of irrigation access points that are privately owned by the household is conceptualized and referred to as 'water stack'. As the size of the water stack increases, resilience of the household is built-up, however it is the quality of the water stack that will determine the long-term resilience secured by it. In the absence of resource use norms in the community, households are more likely to invest in a water stack that increases house sustainability, but at the expense of resilience of the micro-watershed system and thereby the long-term livelihood sustainability of the community as a whole.

Enforcement of resource use norms safeguard resource system resilience and, coordination in resource use is most likely to emerge when the community is sensitized to the potential loss in agricultural income as a consequence of non-cooperation. An agricultural extension agency or any similar institution which is capable of vividly illustrating potential income loss to the community due to non-cooperation is most likely in a position to influence local institution of resource governance. As the community had organized itself during the project implementation phase for gaining access to irrigation and thereby enhance livelihood benefits, additional information on resource use impacts could be the trigger that local institutions of resource governance can use for encouraging collective action for the second time. Additionally, influencing resource user norms prior to appearance of destructive resource use practices is favourable to norm enforcement in the community.

Agricultural income is the decisive variable in encouraging second order collective action, therefore the natural potential of the watershed is a binding constraint in the pursuit of long-term resilience. In resource rich regions, the potential loss of agricultural income as a result of non-cooperation is high, encouraging the community to enforce resource use norms. Further, once resource use norms are enforced, the community may depend on the market (non-local) solution to build livelihood stability. In other words, the community may be ready to pay a price for safeguarding resource stability. Farmers imported water for horticulture farming rather than investing more in groundwater extraction. This investment behaviour is influenced by both, the financial viability of earning a satisfying net agricultural income despite increase in cost of cultivation as a result of water imports.

In resource poor regions, the lower potential for agricultural income generation discourages farming households from giving value to the time and effort required for collective action. In the face of a falling interest in undertaking collective action, future programmes might focus on encouraging high income generating agriculture allied activities such as livestock. Achieving collective action in that sector, is likely to encourage the fostering of trust needed for collective management of the scarce groundwater resource. In the absence of such a form of intervention it might be the case of that farming households with low and declining agricultural income will only consider collective action options, after encountering greater levels of distress or even a collapse in their rural livelihoods.

Chapter 3

Conclusions

The Watershed Development Programme (WDP) in India facilitates sustainable agricultural livelihoods by rejuvenating the natural resource base within an identified area. WDP implementation provides irrigation to farming households accessed through wells. Increased availability of irrigation encourages agricultural ambition and active groundwater extraction. In the absence of effective monitoring of resource extraction, its depletion is inevitable. Effective local governance is crucial to resource sustainability but the elusive nature of groundwater poses challenges.

WDP is a crucial programme for poverty reduction and livelihood improvement of farming households in the semi-arid regions of India. Afforestation and water harvesting efforts together check land resource degradation and provide an opportunity to increase water availability and agricultural income. Participatory planning is identified as the key to successful programme implementation. The focus of this research is on identifying factors that aid sustainable management of micro-watershed after programme implementation. Effective and sustained management of watershed by the community can result in consistent livelihood gains. This thesis evaluates the interplay of knowledge of resource system, social capital, sustainability of resource using Ostrom's Socio Ecological System (SES) framework.

The elusive nature of groundwater resources results in impacts that are not easily and immediately perceivable to resource users. Farmers acting in their individual interest may extract water quicker than the rate at which rainfall is harvested and groundwater tables are recharged within the watershed, leading to resource depletion. Water resource semi-arid regions are more prone to such risks. Support for monitoring from organisations with the requisite knowledge advantage such as agricultural extension agencies, is shown to aid the community in this regard. These institutions are capable of disseminating crucial information regarding resource use and its impact on sustainability of the resource.

In the first essay, this research evaluates the role of collective knowledge of the resource system (U7), and importance of the resource to its users (U8) play in encouraging effective management - two features identified in SES framework. The results show that farmers who demanded more water from the watershed, were also the ones who engaged more actively with agricultural extension agency. Collective engagement encourages development of site-specific resource management strategies safeguarding resource sustainability. Further, these farmers also adapted irrigation practices to bolster efficiency. This research aligns with evidence that resource users who are more dependent on the resource are the ones who value its sustainability (Gibson, 2001). Increased collective awareness among users about the resource system is likely to revive collective action (Ostrom, 2009); in the same manner that collective action by the community was mobilized for the implementation of WDP (D'Costa and Samuel, 2001).

Having evaluated the effect of collective knowledge and engagement with extension agency on the water demand of the farmers, in the second essay of this thesis, the significance of social capital in this context is established. Increased availability of irrigation post WDP encourages farmers to pursue higher agricultural ambitions and consequently demand more irrigation. To match increased irrigation demand farmers may choose to invest in further groundwater extraction, risking resource depletion. Alternatively, encouraging farmers to invest in farm level water harvesting measure to fulfil, at least a share of the increased demand; may contribute to groundwater resource health.

Specifically, the role and importance of the resource (U8) and social capital (U6) in the community – from Ostrom's SES framework has been evaluated for watersheds. It is shown that collective action and resource use norms emerge, when agricultural income of farming households are high in the community. Social capital in the community is shown to play a significant role in enabling more households in the community to invest in water harvesting, thereby facilitating adherence to resource use norms banning over extraction of groundwater resources.

Next, this study identifies factors that influence a household's investment in water conservation efforts. Conservation investment by individual farming households have both private and public benefits. Private benefits as a result of diversified sources of irrigation and public benefit from reduced individual dependence on common groundwater. Post WDP, the irrigation availability in the watershed communities increases, consequently crop choices and cropping patterns change. It is the higher income that accrues from agriculture that encourages farmers to invest in conservation efforts; an observation similar to Gibson (2005) in the case of households depending on forest produces.

Groundwater resource is a common resource, however as the access to this resource is privately held, farmers tend to act in self-interest (Joshi et al, 2004). The elusive nature of groundwater makes it difficult to gauge the impact of resource use, or, farmers are not fully aware of how their water extraction actives impact the health of the resource system as a whole.

Therefore, institutions that have knowledge advantage can play a key role in helping local resource governance institution to spread awareness regarding conservation in the community. The agency also helps identify appropriate resource use norms.

Setting up an ecosystem that enables the adoption of water conservation measures can encourage many more farmers in the community to invest in the same initiative. Social network in the community enables setting up of such conducive circumstance. When a larger share of the community is able to take up horticulture farming and invest in conservation, safeguarding resource health become the need of the community.

In the third essay of this thesis, the attitude of farmers towards sustainability of the water resource, and its dependence on socio-economic variables is studied in further detail. Farmers change their crop choices to include high value commercial crops, and/ or shift their farming pattern to bring more land under commercial cultivation after the Watershed Development Programme implementation. Consequently, irrigation demand from the watershed system increases and farmers strive to secure their irrigation requirements by individually and privately investing in multiple irrigation access sources, a phenomenon referred to as 'water stack' in the study. The constituents of the water stack are influenced by resource use norms. In communities with no norms governing groundwater use; all the constituents of the water stack will depend more on groundwater for irrigation. While in communities that enforce norms, the constituents of a water stack include sources other than groundwater. Briefly, irrigation sufficiency is built at the expense of watershed system resilience in the absence of norms. Formulation and enforcement of norms are more likely to occur when potential loss of livelihood as a result of non-cooperation among resources are high.

The relation between household livelihood sustainability and resilience building is established. Access to irrigation is the primary means to enhance livelihood sustainability among households in watershed communities located in the semi-arid regions. To bring in more land under irrigated cultivation or to sustain the current share of land under irrigated cultivation, households invest in water stack. As its size increases, resilience of the household is built-up, however it is the quality of the water stack that determines the long-term resilience. In the absence of resource use norms in the community, households are more likely to invest in a water stack that increases sustainability at an individual household level, but at the expense of resilience of the micro-watershed system, and thereby the long-term livelihood sustainability of the community as a whole.

Enforcement of resource use norms safeguard resource system resilience and, coordination in resource use is most likely to emerge when the community is sensitized to the potential loss in agricultural income as a consequence of non-cooperation. An agricultural extension agency or any similar institution which is capable of vividly illustrating potential income loss to the community due to non-cooperation is most likely in a position to influence local institution of resource governance. Additionally, influencing resource user norms prior to appearance of degenerative resource use practices is favourable to norm enforcement in the community.

Agricultural income is shown to be the decisive variable in encouraging second order collective action, therefore the natural potential of the watershed is a binding constraint in the pursuit of long-term resilience. In resource rich regions, the potential loss of agricultural income as a result of non-cooperation is high, encouraging the community to enforce resource use norms. Further, once resource use norms are enforced, the community may depend on the market (non-local) solution to build livelihood stability. In other words, the community may be ready to pay a price for safeguarding resource stability. Farmers in one of the villages studied imported water for horticulture farming rather than investing more in groundwater extraction. This investment behaviour is influenced by both, the financial viability of earning a satisfying net agricultural income despite increase in cost of cultivation as a result of water imports.

In resource poor regions, the lower potential for agricultural income generation discourages farming households from giving value to the time and effort required for collective action. In the face of a falling interest in undertaking collective action, future programmes might focus on encouraging high income generating agriculture allied activities such as livestock and achieving collective action in that sector. Such activities are likely to encourage the fostering of trust needed for collective management of the scarce groundwater resource. Importantly, adoption of new livelihood strategies requires provision of ease of market accessibility too – a crucial trigger in encouraging households to adopt new strategies. In the absence of such a form of intervention it might be the case of that farming households with low and declining agricultural income will only consider collective action options, after they encounter greater levels of distress or even a collapse in their rural livelihoods.

3.1 Future work

The key inferences that can be drawn from the current thesis was, (i) natural resource constrains are hard to overcome even with resource rejuvenation programmes; (ii) villages are heterogenous and requires specific solutions, they also need continued support in the post-programme phase for its well-functioning; and finally, (iii) income is the key factor influencing decision making with respect to resource use. The results point to the need for future research that focuses on understanding the potential of institutions in the local sphere (farmers' cooperative, marketing agencies, or agricultural extension services) to encourage resource management and thereby livelihood sustainability. The possibility of developing detailed data bases at the cluster level and/or watershed level will permit a more holistic understanding of sustainable water management to ensure better and more stable rural livelihoods.

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Appendix

English translation of the questionnaire used for household survey

CONFIDENTIAL

Booklet Number	**SAMPLE**	**For the purpose of academic research only**

CONSENT STATEMENT

(A briefing regarding the project and its purpose will be provided before the consent is requested)

Study Tittle:	**Watershed Development in India**
Researcher:	**Rekha Avinash Bhangaonkar**
Affiliation:	**PhD Student, Centre of Development Studies, Department of Politics and International Studies, University of Cambridge. U.K.**
Research Support Organisation:	**XXXXXXXXXX**

Do you agree to be interviewed?

Yes / No

Name of the Data enumerator: **Interviewer's initials:**

-- **---**

Interview date: **Place: XXXXXXXX**

Interview Start Time: ---

I	HOUSEHOLD IDENTITY – Information of head of the household			
1.1	Name of the respondent: ---		1.2 Relation with the head of the household: ---	
2.	Name of the head of the household: ---			
3.1	Place of birth of the head of the household --	3.2 Village ------------------------	3.3 Taluka -----------------------------	3.4 District ------------------------
4.1	Religion: ------------------------------------	4.2. Caste: -------------------------------		

II	HOUSEHOLD ROSTER – information of members of the household				
5.1	Please tell me the names of all the people who live and take meals in this house	5.2 Age	5.3 Gender **(O)**	5.4 What is [NAME]'s relation with the head of the household?	5.5 Is [NAME] married? Please circle **(O)** the option. 1- Married = M 2- Not Married = N.M 3- Widowed = W 4- Separated / Divorced = S
(1)	Karta' name		M / F		M NM W S
(2)			M / F		M NM W S
(3)			M / F		M NM W S
(4)			M / F		M NM W S
(5)			M / F		M NM W S
(6)			M / F		M NM W S
(7)			M / F		M NM W S
(8)			M / F		M NM W S
(9)			M / F		M NM W S

5.1	**Name**	**5.2 Age**	**5.3 Gender**	**5.4 Relation to kartha**	**5.5 Marital status**
(10)			M / F		M NM W S
(11)			M / F		M NM W S
(12)			M / F		M NM W S

III **NON-RESIDENT HOUESHOLD MEMBERS – Information regarding people living away from home**

6. Do any women in the household have **husbands** who do not live in the household?

	6.1 Name	6.2 Relation with the head of the household	6.3 Gender **(O)**	6.4 Age	6.5 Place of residence	6.6 State	6.7 Has been away for?	6.8 What does he/she do?
(1)			M F					
(2)			M F					
(3)			M F					

7. Do any men in the household have **wives** who do not live in the household?

	7.1 Name	7.2 Relation with the head of the household	7.3 Gender **(O)**	7.4 Age	7.5 Place of residence	7.6 State	7.7 Number of years the person has been staying away	7.8 What does he/she work as?
(4)			M F					
(5)			M F					
(6)			M F					

IV MIGRATION

8. For how many years has the family been living in this village? **(O)**

(A) Since his grandfather's time **(B) Since his father's time** **(C) First generation**

***9. Ask 10, only if 9 (c) is (O)** What was the reason for migrating to this village?

10.Did anyone in this family seek work outside the village before WSD? **(O)** **Yes** **No**

11. Who in the family went out for work?

	11.1 1Name	11.2 Gender **(O)**	11.3 How often did they go out to work? *Eg: Months in a year, ...*
(1)		M F	
(2)		M F	
(3)		M F	
(4)		M F	

12. Did any of your neighbours migrate? **(O)** **Yes** **No** **If YES ask question 14**

13.What do you think was the main source of income of that household?

V. **EDUCATION IN THE HOUSEHOLD**

14.1 The highest educational qualification of the man of the house? *(Please circle **(O)** the answer)*

1 2 3 4 5 6 7 8 9 10 11 12 Diploma Degree Post Graduate Others

14.2 Medium of school education: *(Please circle **(O)** the answer)* **(A) Marathi** **(B) English** **(C) Others**

15.1 The highest educational qualification of the lady of the house? *(Please circle **(O)** the answer)*

1 2 3 4 5 6 7 8 9 10 11 12 Diploma Degree Post Graduate Others

15.2 Medium of school education: *(Please circle **(O)** the answer)* **(A) Marathi** **(B) English** **(C) Others**

16. Educational qualification of the children in the house? *(Please circle **(O)** the answer)*

	16.1 Name	16.2 Medium E = Eng. M= Marathi **(O)**	16.3 Primary **(O)**	16.4 Secondary **(O)**	16.5 High school **(O)**	16.6 Diploma/Graduate **(O)**	16.7 Professional/ others
(1)		E M	1 2 3 4	5 6 7	8 9 10 11 12	Dip. Grad. PG	
(2)		E M	1 2 3 4	5 6 7	8 9 10 11 12	Dip. Grad. PG	
(3)		E M	1 2 3 4	5 6 7	8 9 10 11 12	Dip. Grad. PG	
(4)		E M	1 2 3 4	5 6 7	8 9 10 11 12	Dip. Grad. PG	
(5)		E M	1 2 3 4	5 6 7	8 9 10 11 12	Dip. Grad. PG	

16.8 Who in this household clears doubt or discuss school lessons with children at home? (Please circle **(O)** the answer.)

(A)Lady of the house **(B) Man of the house** **(C) Other elders** **(D) Elder Siblings** **(E) None**

17. Is there any family member who is **student** and is living away for college or **school**?

	4.1 Name	4.2 Relation with the head of the household	4.3 Gender **(O)**	4.4 Age	4.5 Place of residence	4.6 State	4.7 Has been away for?	4.8 What does he/she study?
(1)			M F					
(2)			M F					
(3)			M F					

18. Does the man of the house read newspaper? **(O)** **Yes** **No**

19. Does the lady of the house read newspaper? **(O)** **Yes** **No**

VI. AGRICULTURAL LAND

20.1 Total agricultural land owned ------------------------- acers 20.2 Land cultivated ---------------------------- acres

If NO land is owned. GOTO 24

Rented out

22.1 Any Land that's rented **out** --------------------------------- acres

22.2 Do you receive cash/ crop for land rented out to tenant? **(O)** **(A)**Cash (B) Crop (C)Both

22.3 If cash, how much do you receive during a year for the land? ---

22.4 If crop, what proportion of the crop do you receive? --

Rented in

23.1 Any Land that's rented **in** -------------------------------- acres

23.2 Do you pay cash/ crop for land rented in to the landlord? **(O)** **(A)**Cash (B)Crop (C)Both

23.3 If cash, how much do you pay for a year? ---

23.4 If crop, what proportion of the crop do you take? --

Sharecropping

24.1 Any Land that's rented **in** -------------------------------- acres

24.2 Do you pay cash/ crop for land rented in to the landlord? **(O)** **(A)Cash** **(B)Crop** **(C)Both**

24.3 If cash, how much do you pay for a year? ---

24.4 If crop, what proportion of the crop do you take? --

VII **IRRIGATION**

25. In all, how much of the land you cultivate is irrigated? -------------------- acers (all time)

26. In each of the season, how much of the land you cultivate is irrigated?

(26.1) All season --------- acre (26.2) Kharif-----------acre (26.7) Rabi -----------acre (26.8) summer ---------- acre

27. What are the sources of irrigation water? **(O)**

(A) Wells (B) Farm pond (C) Tube well (D) Community well (E) Others --------------------

Only to households who have a well:

28.1 What is the depth of your well? ------------------------ ft 28.2 Year of installation: --------------------------

29.1 Do you keep a track of the water levels in your well? **(O) Yes No**

30.1 If **Q. 29** is **YES**, how do you keep a track of the water level?

(A) Judgement by looking at the water level in the well

(B) Judgement by a measurement stick/gauge

(C) Others (Please specify): --

30.2 If **Q. 29** is **YES**, how often do you keep track of water levels in the well?

(A) Before I irrigated the field **(B)** After I irrigated the field **(C)** I follow a routine of monitoring

(D) I decide it randomly **(E)** Others (Please specify): ---

31.1 Does any organization visit you to check the level of water in your well? **(O) Yes No**

31.2 If so, please share the name of that organisation ---

Only to households who have a plastic pond:

32.1. What is the capacity of your farm pond? ----------------------------**unit** 32.2. Year of installation: ---------------------------

33. In all, how much did you spend on your farm pond? Rs ------------------------------

34. How often do you refill your plastic pond? **(O)**

(A) Daily **(B)** Once in 2 to 3 days **(C)** Weekly **(D)** Fortnightly **(E)** Please specify: -------------------------------

35. What is the rating of your water pump?

(A) Power ------------------------ (HP) **(B)**Head --------------------- mts **(C)** Output--------------------- litres/min

36. Does it have a diesel or generator back up? **(O) Yes No**

38.1 Do you face electricity outrages? **(O) Yes No**

38.2 If so how often do you face electricity shortages?

38.3 On an average, how long would be electricity be gone then? -------------- hrs

39. Do you share water from your well or pond with anybody else for irrigation purposes? **(O)** **Yes** **No**

36. How do you understand the water requirements of your crops?

(OR) what signs do you look for to understand the water requirements of your crops?

(A) Grapes/ horticulture plants: ---

(B) Non-horticulture plants: ---

(C) Irrigates based on a routine **(O)** **Yes** **No**

37. Do you coordinate irrigation of your field along with the irrigation in the neighbouring field? **(O)**

(A) Yes **(B)** No **(C)** Sometimes

38. Did you incur any expenditure on tanker last year? **(O)** **Yes** **No**

39. If **Q.38 is YES**, what was the expenditure and in which season did you incur this expense?

(A) All season	**(B)** Kharif	**(C)**Rabi	**(D)**Summer
Rs --------------------	Rs ------------------	Rs -------------------	Rs -------------------

40. Have there been instance when you felt that you could not irrigate your fields very well in the last two years? **(O)**

(A) Never **(B)** Very rarely **(C)** Often

X AGRICULTURAL DECISION MAKING

41. Who is the primary decision maker regarding farm matters? Name: --

42.1 Does he/she discuss farm matters at home? **(O)** **Yes** **No**

42.2 If **Q.42.1 is Yes**, with whom the discussion happens mostly? Name: --

Decision making at the household level

43. Does he/she discuss the agricultural affairs with any friends? **(O)** Yes No

44. If **Q. 43 is Yes**, could you please name two of his good friends with whom agricultural affairs are discussed?

1. ---
2. ---
3. ---

45. If **Q. 43 is Yes**, how often does he/she meet friends in a month? **(O)**

(A) More than once in week **(B)** Weekly **(C)** Fortnightly **(D)** Once in a month *(meeting encourages learn)*

46. If **Q. 43 is Yes**, how are the meetings decided? **(O)** *(Multiple answers are fine)*

(A) Planned meetings **(B)**Meets as per need arises **(C)** Unplanned - Friendly meetings

Self-organizing

47.1Is he/she a member of any agriculture cooperative/ self-organized organization **in this village**? **(O)** **Yes** **No**

47.2 Name of this organisation: ---

47.3 How often does this group meet in a month?

(A) More than once in week **(B)**Weekly **(C)**Fortnightly **(D)**Once in a month

48. Is he/she a member of any agriculture cooperative/ self-organized organization **outside this village**? **(O)** **Yes** **No**

46.2Name of this organisation: ---

46.3How often does this group meet? **(O)**

(A) Monthly **(B)** Once in 2 months **(C)** Once in 3 months **(D)** Half yearly **(E)** Annually

Circle of Influence

49. Are you a member of any WhatsApp Group for agricultural affairs? **(O)** **Yes** **No**

50. If **Q. 49 is Yes**, who initiated creation of this group? **(O)**

(A) You **(B)**Friends **(C)**Agricultural organisation **(D)** Panchayat **(E)**Others

51. **Q. 49 is Yes**, Has any agriculture related info shared in this WhatsApp group been useful to you? **(O)** **Yes** **No**

52. **Q. 49 is Yes**, have you based any of your decisions on the information that was sent in the WhatsApp group? **(O)** **Yes** **No**

53. **Q. 49 is Yes**, Are there members from other villages in this group? **(O)** **Yes** **No**

54. Does the agricultural decision maker in this household seek any form of advisory (s)? **(O)** **Yes** **No**

	47.1Advisory	47.2 Yes / No **(O)**	47.3 Organisation's name	47.4 Form of communication M = text message C = voice message P = personal communication **(O)**	47.5 Fees/ charges paid
1.	Weather	Y N		M C P	₹
2.	Crop	Y N		M C P	₹
3.	Market	Y N		M C P	₹
4.	Any others (please specify) -----------------------------------	Y N		M C P	₹

55. When all do you consult KVK Jalna for guidance? **(O)** *Multiple answers are fine*

(A) In case of adding/changing to a new variety of crop
(B) For irrigation based enquiries
(C) Before making new forms of agricultural investments
(D) For advice on agriculture allied activities e.g. livestock related, food processing
(E) For information on agricultural trainings/ discussion forums

(F) In case of crop loss/ bad performance in a particular year

(G) Market advice

(H) Use of fertilizers/pesticides

(I) I do not consult them for any matters

56. How would you rate the support of this extension? **(O)**

(A) Excellent **(B)** Very Good **(C)** Good **(D)** Satisfactory **(E)** Poor

57. Has anybody in the household received any form of agricultural training? **(O)** **Yes** **No**

58. Name of the person(s) who has received training

	Name	Last year of training	Purpose of training	Duration of the Course	Training Organization	Fees paid
1.						₹
2.						₹
3.						₹

Extend of *skill building*

AGRICULTURAL INSURANCE

59.1 Do you have agricultural insurance? **(O)** **Yes** **No**

59.2 Name of the policy ---

59.3 What does the insurance cover for? **(O)** **(A)** Crop yield insurance **(B)** Rainfall insurance

59.4 Year in which policy was taken: ---------------------------------

59.5 Insurance premium paid: Rs--------------------------- **(O)** monthly/ bi-monthly/ quarterly/ half-yearly/ annually/ others

60.1 When was the last time you suffered from a complete loss of at least a crop? **(Year)**------------------------

60.2 What was the reason for the loss of that crop --

60.3 Where you able to claim insurance then? **(O)** **(A)** Yes (Insured) **(B)** No (Insured) **(C)** Not insured then

Adaptation

	AGRICULTURAL ASPIRATIONS (under construction)
	*Now I will ask you certain questions about aspirations as a farmer? (**Select only one option please**)*
61.1	Regarding your cropping choice, what would you like to do in the future? Do you wish to……. **(O)**
	(A)Move to or cultivate of more high value crops (B)Move to or cultivate of more staple crops
	(C)Move to or cultivate of more food crops (D)Continue mostly with the current crop choice
61.2	Regarding your natural assets, what would you like to add in the future? Do you wish to……. **(O)**
	(A)Add some more cultivable land (B)Increase the capacity of your well

	(C)Increase the capacity of your plastic pond (D)Continue mostly with the asset mix
61.3	Regarding membership in village committees, what would you like to do in the future? Do you wish to……. **(O)**
	(A) Avail membership in an agricultural cooperative (B)Avail membership of a financial cooperative
	(C) Avail membership of a marketing cooperative (D)Continue mostly with the current memberships
62.1	Do you wish your son(s) to settle in a bigger town/ city? **(O)** **Yes** **No**
62.2	Do you wish your daughter (s) to settle in a bigger town/ city? **(O)** **Yes** **No**
62.3	Do you wish your son/daughter to continue with agriculture as their **main** source of income? **(O)** **Yes** **No**
62.4	Do you wish your son/daughter to continue with agriculture as their **allied** source of income? **(O)** **Yes** **No**
63.	At present, are you satisfied with the income you derive from agriculture? **(O)**
	(A)Satisfied (B) Believe can do better (C) Dissatisfied

	XI AGRICULTURAL PRODUCTION					
64	64.1 Name of the crop Crops? Include self-consumption too	64.2 Area Under cultivation	64.3 Production Total production *(include landlords share, if rented in)*	64.4 Quantity Sold	64.5 Market Price Received?	64.6 Where you satisfied with the price you received?
	Horticulture crops					
1		Unit:	Unit:	Unit:	Unit:	Y N
2		Unit:	Unit:	Unit:	Unit:	Y N
3		Unit:	Unit:	Unit:	Unit:	Y N
	Kharif crops					
1		Unit:	Unit:	Unit:	Unit:	Y N
2		Unit:	Unit:	Unit:	Unit:	Y N
3		Unit:	Unit:	Unit:	Unit:	Y N
4		Unit:	Unit:	Unit:	Unit:	Y N
5		Unit:	Unit:	Unit:	Unit:	Y N
6		Unit:	Unit:	Unit:	Unit:	Y N
	Rabi crops					
1		Unit:	Unit:	Unit:	Unit:	Y N
2		Unit:	Unit:	Unit:	Unit:	Y N
3		Unit:	Unit:	Unit:	Unit:	Y N
4		Unit:	Unit:	Unit:	Unit:	Y N
5		Unit:	Unit:	Unit:	Unit:	Y N
6		Unit:	Unit:	Unit:	Unit:	Y N
	Summer crops					
1		Unit:	Unit:	Unit:	Unit:	Y N
2		Unit:	Unit:	Unit:	Unit:	Y N
3		Unit:	Unit:	Unit:	Unit:	Y N
4		Unit:	Unit:	Unit:	Unit:	Y N

	XI AGRICULTURAL PRODUCTION				
64	64.7 What was the expected market price?	64.8 Where did you sell your produce? (Name of the market) **(O)**	64.9 Irrigated? Yes / No **(O)**	64.10 Water use Sp = Sprinkler D = Drip F = Flood **(O)**	64.11 Since when have you been growing horticulture crops?
	Horticulture crops				
1			*Y N*	Sp D F	Year---------------
2			*Y N*	Sp D F	Year---------------
3			*Y N*	Sp D F	Year----------------
	Kharif crops				
1			*Y N*	Sp D F	
2			*Y N*	Sp D F	
3			*Y N*	Sp D F	
4			*Y N*	Sp D F	
5			*Y N*	Sp D F	
6			*Y N*	Sp D F	
	Rabi crops				
1			*Y N*	Sp D F	
2			*Y N*	Sp D F	
3			*Y N*	Sp D F	
4			*Y N*	Sp D F	
5			*Y N*	Sp D F	
6			*Y N*	Sp D F	
	Summer crops				
1			*Y N*	Sp D F	
2			*Y N*	Sp D F	
3			*Y N*	Sp D F	
4			*Y N*	Sp D F	

VIII	COST OF PRODUCTION (*Please refer answers to question 30 for crops grown)* Now I will ask you some details regarding cost of agricultural production						
65.	**Crops?**	65.1 Seed cost **(Total)**	65.2 Fertilizer **(Total)**	65.3 Manure **(Total)**	65.4 Pesticide **(Total)**	65.5 Farm equipment / tractors / draft animals **(Total)**	65.6 Hired Labour cost **(Total)**
	Horticulture crops?						
1		Rs	Rs	Rs	Rs	Rs	Rs
2		Rs	Rs	Rs	Rs	Rs	Rs
3		Rs	Rs	Rs	Rs	Rs	Rs
4		Rs	Rs	Rs	Rs	Rs	Rs
	Kharif crops?						
1		Rs	Rs	Rs	Rs	Rs	Rs
2		Rs	Rs	Rs	Rs	Rs	Rs
3		Rs	Rs	Rs	Rs	Rs	Rs
4		Rs	Rs	Rs	Rs	Rs	Rs
5		Rs	Rs	Rs	Rs	Rs	Rs
6		Rs	Rs	Rs	Rs	Rs	Rs
65.	**Rabi crops?**						
1		Rs	Rs	Rs	Rs	Rs	Rs
2		Rs	Rs	Rs	Rs	Rs	Rs
3		Rs	Rs	Rs	Rs	Rs	Rs
4		Rs	Rs	Rs	Rs	Rs	Rs
5		Rs	Rs	Rs	Rs	Rs	Rs
6		Rs	Rs	Rs	Rs	Rs	Rs
65.	**Summer crops?**						
1		Rs	Rs	Rs	Rs	Rs	Rs
2		Rs	Rs	Rs	Rs	Rs	Rs
3		Rs	Rs	Rs	Rs	Rs	Rs
4		Rs	Rs	Rs	Rs	Rs	Rs

	CROP STORAGE
66.	Do you avail storage/ cold storage facilities for any of your crops? **(O)** **Yes** **No**
66.1	If Q. --- Yes, for which all crops do you avail storage/cold storage facilities? (Please list the crops below)

1.	2.	3.	4.
5.	6.	7.	8.

XI. PERCEPTION ON CLIMATE CHANGE AND ITS EFFECTS (Adaptation strategies?)

66. Do you feel that the weather has changed in the past few years? **(O)** **Yes** **No**

67. If **Q.66 is YES**, what about the weather has changed? **(O)** *(Multiple answers are fine)*

(A) average temperature increase (B) average temperature decreases (C) variability in temperature

(D) average rainfall increase (E) average rainfall decrease (F) rainfall variability

(G) variability in June – July rainfall (H) variability in seasonal cycles (I) instance of cold winds

(J) instances hailstorm (K) mismatch of nakshatram / panchakam (L) unseasonal rain

68. How has the average increase in temperature conditions affected your agriculture?

68.1 Grapes/ other horticulture crops: (**O**)
(A) Has not affected at all
(B) Plant reaches harvesting quickly
(C) The grape vines are smaller in size
(D) The grape vines are less sweet /crisp
(E) None of the above

68.2 Non-horticulture crops: (**O**)
(A) Has not affected at all
(B) Plant reaches harvesting quickly
(C) Grains per plant has declined
(E) None of the above

IX HOUSEHOLD LABOUR

69. Now I would like to ask about the people in the household who helped to work on the farm in the last 12 months?

	69.1 Name	69.2 Number of days worked	69.3 Number of hours worked in a typical day	69.4 Typical activity performed

1	Name	Days	Hrs	
2	Name	Days	Hrs	
3	Name	Days	Hrs	
4	Name	Days	Hrs	
5	Name	Days	Hrs	
6	Name	Days	Hrs	

X	**LIVESTOCK**
70.	Does this household own any livestock? (Please tick from the options below)

70.1	Animal	Yes/ No **(O)**	70.2 How many?		70.1	Animal	Yes/ No **(O)**	70.2 How many?
(a)	Milch cows	*Y* *N*			(e)	Goat	*Y* *N*	
(b)	Bullocks	*Y* *N*			(f)	Sheep	*Y* *N*	
(c)	Buffaloes	*Y* *N*			(g)	Poultry	*Y* *N*	
					(h)	Any others		

71	71.1 How much did you spend buying these animals last year?		71.2 How much is their maintenance cost?	71.3 How much did you earn from these animals?
(a)	Cows and Milch buffaloes	Rs	Rs	Rs
(b)	Draft animals	Rs	Rs	Rs
(c)	Goats and sheep	Rs	Rs	Rs
(d)	Poultry and others	Rs	Rs	Rs

XI	**LIVESTOCK: HOUSEHOLD LABOUR**		
72.	Who in the household ever helped take care of the animals?		
	72.1 Name	72.2 How often did the PERSON help take care of the animals? **(O)**	72.3 Approximate time spend on a day?
(a)		(A) never (B) sometimes (C) usually	--------------hrs
(b)		(A) never (B) sometimes (C) usually	--------------hrs
(c)			

		(A) never (B) sometimes (C) usually	--------------hrs
(d)		(A) never (B) sometimes (C) usually	--------------hrs
(e)		(A) never (B) sometimes (C) usually	--------------hrs

XII	**HOUSEHOLD NONFARM BUSINESS**
A	*Does anybody in this household run their own business, however big or small?* *Does anybody make something for sale, such as cloth or some food like pickles?* *Or does anybody sell something in the market or to the customers of any sort?* *Or does anybody provide a service to others for a price, either a skilled service like a doctor or an unskilled service like a barber?*
73. 74. 75.	Please describe the occupation --- Who runs this business? Name: -- Where does this work mainly take place? **(O)** (A) Home (B) Another fixed place (C) Other moving place
76. 77. 78.	How much did you earn from this business last year? ₹------------------------ How much did you incur as labour cost last year? ₹------------------------ How much was the paid in expenses, such as the costs of materials, rents, interest etc. ₹----------------------

B	**Household Non-Farm Business:** Does anybody in this household run their own business, however big or small?
73. 74. 75.	Please describe the occupation --- Who runs this business? Name: -- Where does this work mainly take place? **(O)** (A) Home (B) Another fixed place (C) Other moving place
76. 77. 78.	How much did you earn from this business last year? ₹------------------------ How much did you incur as labour cost last year? ₹------------------------ How much was the paid in expenses, such as the costs of materials, rents, interest etc. ₹----------------------

C	**Household Non-Farm Business:** Does anybody in this household run their own business, however big or small?
73. 74. 75.	Please describe the occupation --- Who runs this business? Name: -- Where does this work mainly take place? **(O)** (A) Home (B) Another fixed place (C) Other moving place
76.	How much did you earn from this business last year? ₹------------------------

77.	How much did you incur as labour cost last year? ₹------------------------
78.	How much was the paid in expenses, such as the costs of materials, rents, interest etc. ₹----------------------

XIII	**WAGE AND SALARY WORK** Now, **besides work on the household farm or in any of the household's business**, what work for pay or goods did [NAME, from the roster] do last year?					
79.	79.1What kind of work does [NAME] do? Description of the work	79.2 For how many days did [NAME] do this work last year?	79.3 How many hours did [NAME] work in a usual day?	79.4 How much was [NAME] paid in cash for this work? **(per day/ per month/ yearly)**	79.5 Is [NAME] a Casual or a Permanent worker? (Causal/ Permanent) **(O)**	79.6 Was this a government job? If yes, please specify the scheme?
(1)	Name	Day	Hrs	₹	C P	Name
(2)	Name	Day	Hrs	₹	C P	Name
(3)	Name	Day	Hrs	₹	C P	Name
(4)	Name	Day	Hrs	₹	C P	Name
(5)	Name	Day	Hrs	₹	C P	Name

XIV	**SOCIAL SECURITY**
80. 81. 82.	Does the household have a ration card? **(O)** Yes / No (A) APL (white card) (B) APL (red card) (C) BPL (yellow card) (D) Antyoday (green crad) Have you used it in the last six months? **(O)** Yes / No If **NO**, why have you not used the card? **(O)** (A)Too far (B) Financial constrain (C) Poor quality supply (D)No time (E) Irregular supply (F) Others (Please explain) ---
83.	Does anyone in the household have **(O)** 83.1 Health Insurance Yes / No 83.2 LIC/life insurance Yes / No 83.3 Kisan credit card Yes / No

XVI	**HOUSEHOLD CONSUMPTION (Monthly consumption)**				
84.	Please tell me how much of these items have been consumed by the household in past 30 days. (home produced items should be included in the totals)				
	Items	Quantity consumed?	Expenditure?	Home-grown= H, Purchase = P, Both = B **(O)**	Did you buy from ration/PDS shop? **(O)**
(a)	Rice	--------------kgs	Rs--------------------	H P B	Y N
(b)	Wheat	--------------kgs	Rs--------------------	H P B	Y N

(c)	Cereals (Jowar, Millets, Bajari)	--------------kgs	Rs--------------------	H P B	Y N
(d)	All pulses (Moong, Toor, soy etc)	--------------kgs	Rs--------------------	H P B	Y N
(e)	Sugar	--------------kgs	Rs--------------------	H P B	Y N
(f)	Ghee	--------------litres	Rs--------------------	H P B	Y N
(g)	Edible oil and Vanaspati	--------------litres	Rs--------------------	H P B	Y N

	(Monthly Expenditure)			
	Animal products	Quantity consumed?	Expenditure?	Home-grown= H, Purchase = P, Both = B **(O)**
(h)	Eggs	--------------------- dozens	Rs--------------------	H P B
(i)	Chicken	--------------------- Kgs	Rs--------------------	H P B
(j)	Meat	--------------------- Kgs	Rs--------------------	H P B
(k)	Fish	--------------------- Kgs	Rs--------------------	H P B
	In All Expenditure		Rs--------------------	H P B

(l)	**Monthly expenditure on vegetables**	Rs--------------------------	H P B

XVII	**HOUSEHOLD CONSUMPTION (monthly)**	
(a)	Electricity	₹------------
(b)	Paraffin/ kerosene	₹------------
(c)	Telephone/mobile	₹------------
(d)	Cable connection	₹------------
(d)	House rent	₹------------
(e)	Conveyance (petrol, diesel, taxi, rickshaw, etc.)	₹------------
(f)	Domestic help	₹------------

(m) Home Tax ₹--------------------------------	**(n) Water Tax** ₹--------------------------------

XVIII	HOUSEHOLD CONSUMPTION (yearly)	
85.	Now, over the last year, how much did you spend on …….	
(a)	Medical bills	₹------------
(b)	School fees	₹------------
(c)	Tuition fees	₹------------
(d)	Newspaper	₹------------
(e)	Home repair	₹------------
(f)	Household appliances	₹------------

86. Do you own any of these goods? **(O) Multiple answers are expected.**

1. Cycle	2. Motor Cycle /Scooter	3. T.V.	4. Mobile
5. Computer	6. Air conditioning (A C)	7. Car	8. Bio-gas
9. Gas	10. Chulla	10. Mixer/ Grinder	11. Washing Machine
12. Solar lamps	13. Solar hand pumps		

XIX	DRINKING AND DOMESTIC WATER

87. What is the source of drinking and water for domestic purposes? **(Multiple answers are fine)**

66.1 Source of drinking water	66.2 In the premises or not **(O)**	66.3 Distance of the source from the house
(a) Tap	Y N	--------- mts
(b) Open dug well	Y N	--------- mts
(c) Community well	Y N	--------- mts
(d) Borewell	Y N	--------- mts
(e) Others, please specify -------------------------------	Y N	--------- mts

88. Do you face shortage in drinking and domestic water needs?

88.1 Season	88.2 Shortage of drinking water? **(O)**	88.3 Approximately, how long does the shortage last
(a) Summer – good rain year	Y N	--------------- days/months
(b) Summer – bad rain year	Y N	--------------- days/months

	(c) Any other season??	Y N	--------------- days/months

89. How about water needs of cattle in the house?

89.1 Source of drinking water	89.2 In the premises or not **(O)**	89.3 Distance of the source from the house
(a) Tap	Y N	----------------- km
(b) Open dug well	Y N	-------------------km
(c) Community well	Y N	----------------- km
(d) Borewell	Y N	----------------- km
(e) Other, please specify --------------------------------	Y N	----------------- km

90. Do you face shortage in satisfying their drinking water needs? **(O)** **Y** **N**

	DEBT

91.1 Have you taken a loan for agricultural purpose in the last three years? **(O)** **Y** **N**

91.2 In which year did you avail this agricultural loan? **(A)** 2016 **(B)** 2015 **(C)**2014

91.3 If Q.91.1 **is Yes**, what was the loan amount you availed for agricultural purpose in the last three years? ₹-----------------------

91.4 What was the interest paid for this loan? ------------------------- %

91.5 From whom did you avail this loan?

(A) Bank (B) Cooperative Society (C) Savings Groups (D)Relatives/Friend

(E)Govt. Scheme (F) NGO (G) Money lender (H) Others: Please specify

----

91.6 In the last 3 year have you sold any of the following assets to help you repay your agricultural loan?

(A) Land: **(O)** **Y** **N**

(B) Jewellery: **(O)** **Y** **N**

(C) Livestock: **(O)** **Y** **N**

91.7 Do you have any monthly outstanding bills with any grocery shop? **(O)** **Y** **N**

91.8 If **Q.91.7 is Yes**, then please specify the amount outstanding ₹------------------------------

XX	**Social Networks**			
91	Among your acquaintances and relatives, are there anybody who is in the …….	Yes No **(O)**	How is he/ she related to you?	Does the person live in the same village or another? **(O)**

91.1	Medical profession	Y N		Village	Other village
91.2	Teaching profession	Y N		Village	Other village
91.3	Government officer	Y N		Village	Other village
91.4	Your village committee	Y N		~~	~~
91.5	Member of a political party	Y N		Village	Other village

92.	Please name 5 of your friends who are from this village	
(1)	Name	(3) Name
(2)	Name	(4) Name
(5)	Name	

XX	**Social Capital** Now, I would like to know about the groups or organizations that you and others in the household belong to. Does anybody in the household belong to a ……			
93	93.1Group type	93.2 Name of the Person in the household who has the group membership	93.3 Name of the organisation	93.4 How often does the group meet in a month? O = once, W= weekly, F= fortnightly, M= more **(O)**
1.(A)	Savings Group1	Name	Name	O W F M
1.(B)	Savings Group 2	Name	Name	O W F M
1.(C)	Savings Group 3	Name	Name	O W F M
2.(A)	Agri. Cooperative 1	Name	Name	O W F M
2.(B)	Agri. Cooperative 2	Name	Name	O W F M
2.(C)	Agri. Cooperative 3	Name	Name	O W F M
2.(A)	Milk Cooperative 1	Name	Name	O W F M
2.(B)	Milk Cooperative 2	Name	Name	O W F M
3.(A)	Mahila Mandal 1	Name	Name	O W F M
3.(B)	Mahila Mandal 2	Name	Name	O W F M
4.(A)	Religious group 1	Name	Name	O W F M
4.(B)	Religious group 2	Name	Name	O W F M

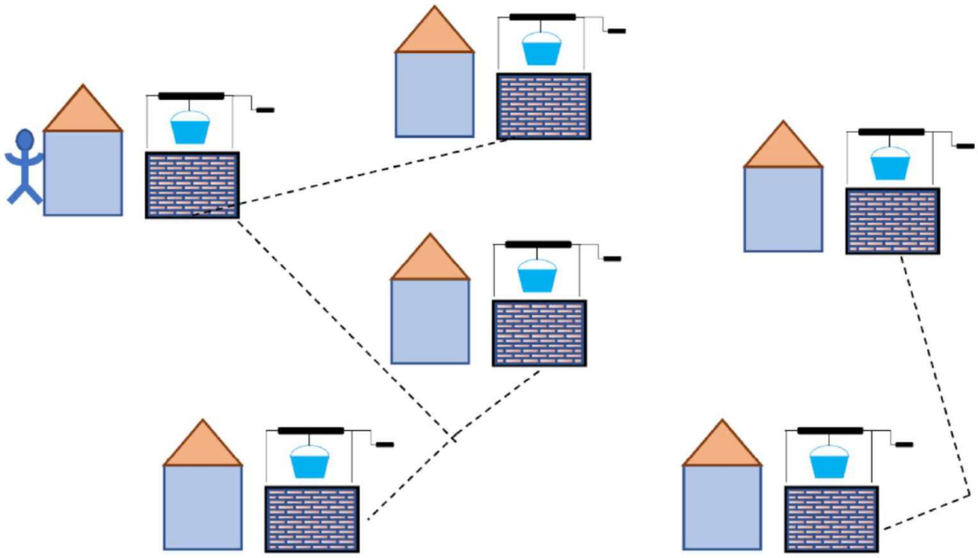
	PARTICIPATION IN LOCAL GOVERNANCE

94.	How many hours do you spend in a month for any work related to the panchayat in this village? ---------------------- hours
95.	Approximately, how many gram sabhas did you attend last year? Number ----------------------
96.1	Who else in the family attends gram sabhas? Name--------------------------------
96.2	How many sabhas did this person attend last year? Number ----------------------
98.	What policies/plans were implemented after watershed development in your village? Could you name any 3 such developments? 1.--- 2.--- 3.---

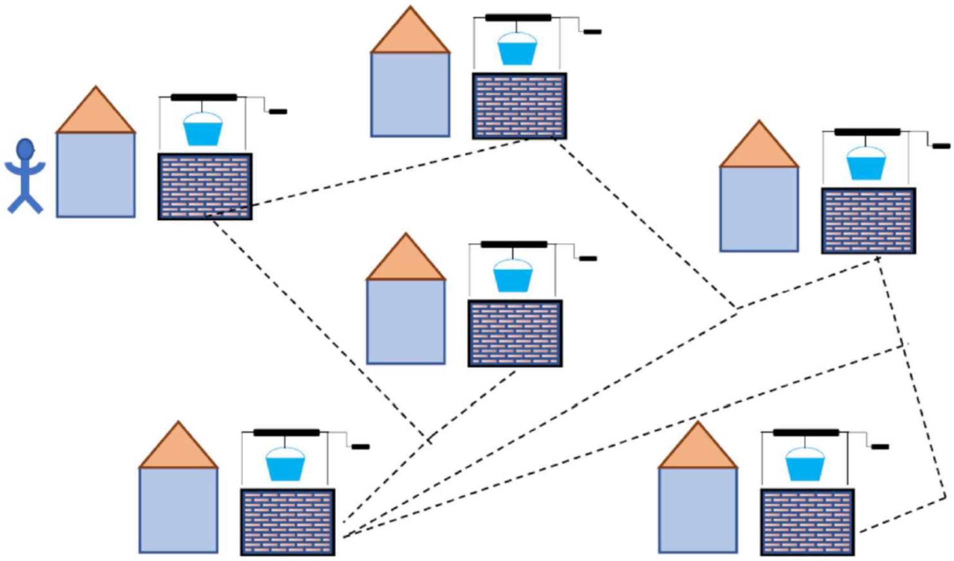
Booklet Number:

Question No1: आपल्या मते या गावातल्या विहिरी कोणत्या रीतीने एकमेकांशी जोडलेल्या आहेत?

पर्याय A



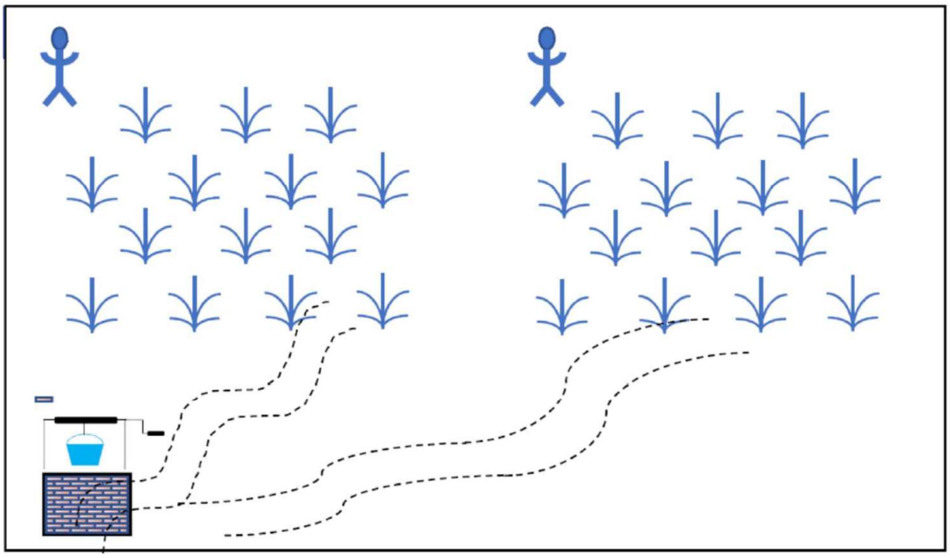
पर्याय B



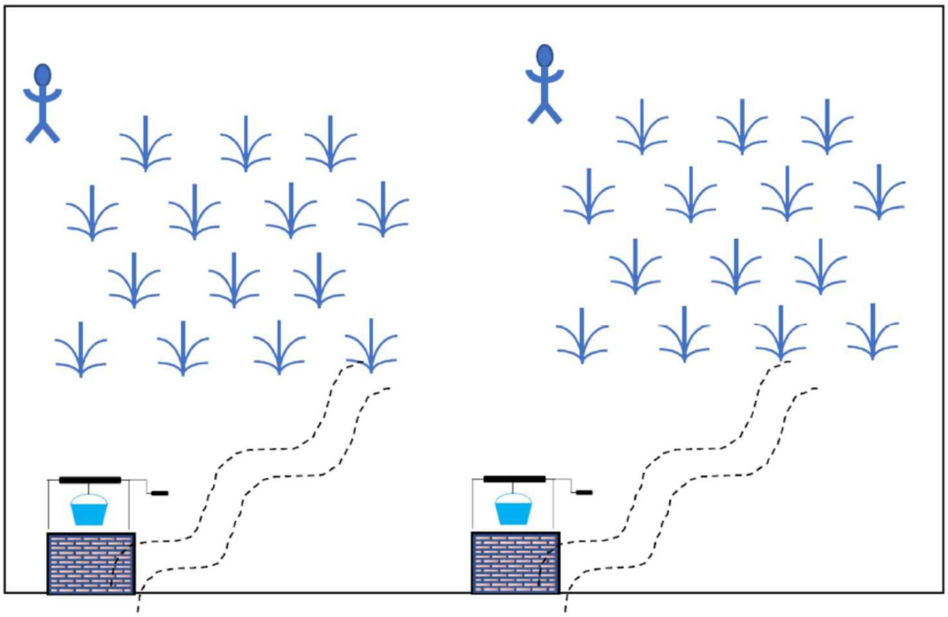
Question 2:

जर तुम्हाला दोन मुले असतील ज्यांना यशस्वी शेतकरी व्हायचे असेल, तर तुमच्या मते त्यांनी त्यांच्या शेतांची आखणी कशी करावी?

पर्याय A

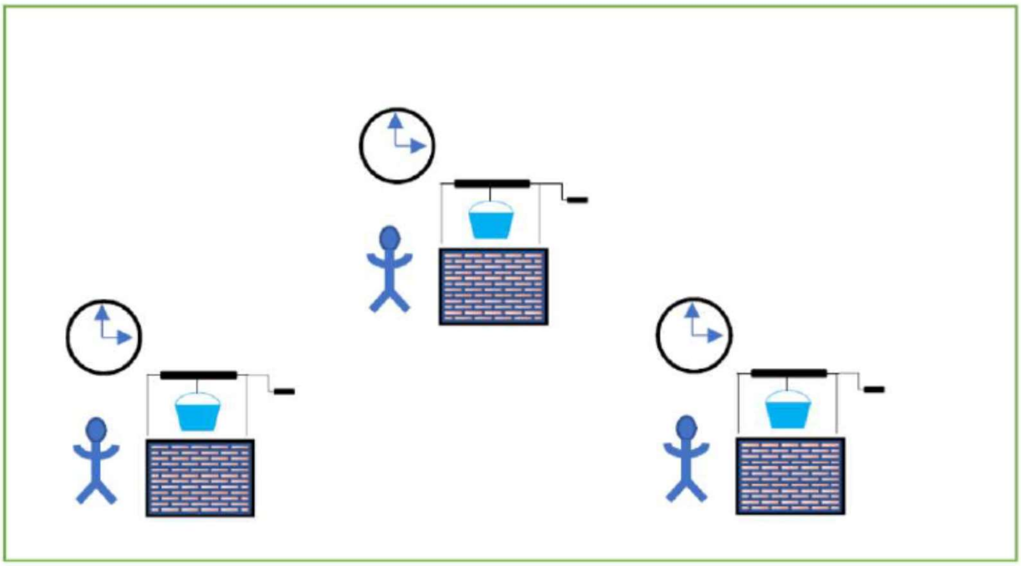


पर्याय B

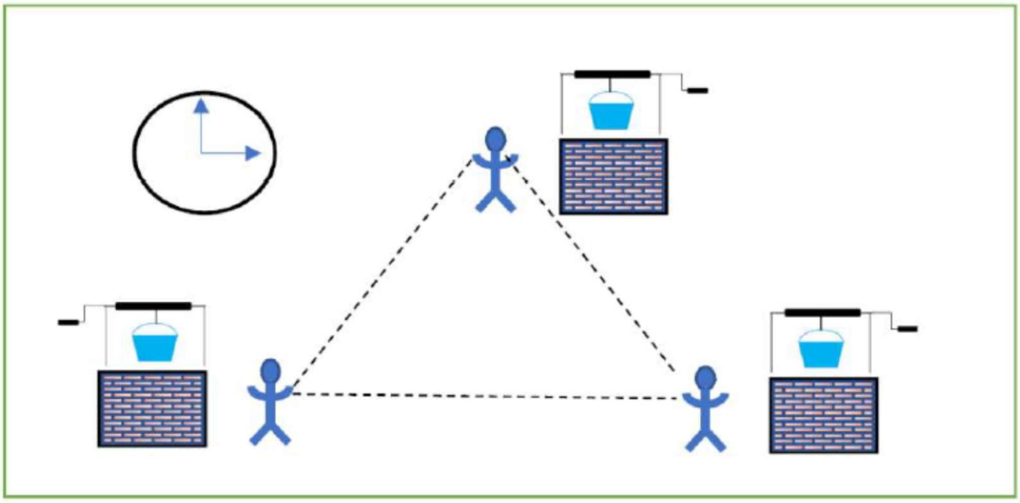


Question3. आपल्या मते आपल्या गावात पाण्याच्या स्त्रोतांचे चांगल्या रीतीने निरीक्षण कसे करता येईल?

पर्याय A: व्यक्ती कडून स्वतः बद्दल



पर्याय B: समूहाकडून त्यांच्याविषयी



पर्याय C: सरकारी किंवा अन्य स्वायत्त संस्था ज्या हा नियम राबवू शकतात